NASA'S ORGANIZATIONAL AND MANAGEMENT CHALLENGES IN THE WAKE OF THE COLUMBIA DISASTER

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COMMITTEE ON SCIENCE

CONTENTS

October 29, 2003

NASA'S ORGANIZATIONAL AND MANAGEMENT CHALLENGES IN THE WAKE OF THE COLUMBIA DISASTER

WEDNESDAY, OCTOBER 29, 2003

HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE,
Washington, DC.

The Committee met, pursuant to call, at 10:10 a.m., in Room 2318 of the Rayburn House Office Building, Hon. Sherwood L. Boehlert [Chairman of the Committee] presiding.

COMMITTEE ON SCIENCE
U.S. HOUSE OF REPRESENTATIVES
WASHINGTON, DC 20515

Hearing on

NASA's Organizational and Management Challenges
Wednesday, October 29, 2003
10:00 a.m. – 12:00 p.m.
2318 Rayburn House Office Building

WITNESS LIST

First Panel

Admiral F.L. "Skip" Bowman
Director,
Naval Nuclear Propulsion Program
U.S. Navy

Rear Admiral Paul E. Sullivan
Deputy Commander,
Ship Design, Integration and Engineering
Naval Sea Systems Command
U.S. Navy

Mr. Ray Johnson
Vice President,
Space Launch Operations
The Aerospace Corporation

Ms. Deborah L. Grubbe, P.E.
Corporate Director – Safety and Health,
DuPont

Second Panel

Admiral Harold Gehman (ret)
Chairman,
Columbia Accident Investigation Board.

HEARING CHARTER

COMMITTEE ON SCIENCE
U.S. HOUSE OF REPRESENTATIVES

NASA's Organizational and Management Challenges in the Wake of the Columbia Disaster

WEDNESDAY, OCTOBER 29, 2003
10:00 A.M.–12:00 P.M.
2318 RAYBURN HOUSE OFFICE BUILDING

1. Purpose

On Wednesday, October 29, 2003 at 10:00 a.m., the House Committee on Science will hold a hearing to address the organizational and management issues confronting the National Aeronautics and Space Administration (NASA) in the aftermath of the Space Shuttle *Columbia* accident. According to the *Columbia* Accident Investigation Board (CAIB), NASA's "organizational culture and structure" had as much to do with the *Columbia*'s demise as the physical causes of the accident. During the course of its nearly seven months of investigation into the causes of the accident, the CAIB encountered an ineffective and disengaged safety organization within NASA that "failed to adequately assess anomalies and frequently accepted critical risks without qualitative or quantitative support." Based on its findings, the CAIB recommended significant changes to the organizational structure of the Space Shuttle Program (detailed below).

To give a sense of some of the ways NASA could be restructured to comply with its recommendations, the CAIB report provided three examples of organizations with independent safety programs that successfully operate high-risk technologies. The examples were: the United States Navy's Submarine Flooding Prevention and Recovery (SUBSAFE) and Naval Nuclear Propulsion (Naval Reactors) programs and the Aerospace Corporation's independent launch verification process and mission assurance program for the U.S. Air Force.

This hearing will provide an opportunity to examine each of these examples in depth, as well as the safety programs of the Dupont Corporation (an acknowledged industry leader in safety), to help determine how NASA should be reorganized.

2. Critical Questions

The CAIB determined that reorganizing NASA is a critical requirement if the Shuttle is to fly safely over the long term. To provide adequate oversight of NASA's reorganization plans, the Committee needs to understand how different organization structures can contribute to safety. To that end, the following questions were submitted in advance to each of the witnesses:

a. What does it mean for a safety program to be "independent"? How can safety organizations be structured to ensure their independence?

b. How can safety programs be organized to ensure that they are robust and effective, but do not prevent the larger organization from carrying out its duties?

c. How do you ensure that the existence of an independent safety program does not allow the larger organization to absolve itself of responsibility for safety?

d. How do you ensure that dissenting opinions are offered without creating a safety review process that can never reach closure?

3. Background

Recommendations of the CAIB and previous reports

Since the loss of the Space Shuttle *Challenger* in 1986, numerous outside experts have reviewed NASA's human space flight safety programs and found them lacking. For instance, in the immediate aftermath of the *Challenger* accident, the Rogers Commission issued recommendations calling for the creation of an independent safety oversight function. Despite NASA's compliance efforts, the U.S. General Accounting Office concluded in 1990 that NASA still "did not have an independent and ef-

fective safety organization." Nine years later, the Shuttle Independent Assessment Team and NASA Integrated Action Team likewise issued findings that were critical of NASA's safety programs and echoed the Roger Commission's call for the creation of an independent safety oversight function. Finally, in 2002, the Space Shuttle Competitive Task Force reiterated the call for an independent safety assurance function at NASA with "authority to shut down the flight preparation processes or intervene post-launch when an anomaly occurs."

In August of 2003, the CAIB released Volume I of its report on the *Columbia* accident. Consistent with previous analyses of NASA's safety programs, the CAIB Report discovered fundamental, structural deficiencies in NASA's safety programs. For example, the report states, "the Shuttle Program's complex structure erected barriers to effective communication and its safety culture no longer asks enough hard questions about risk.. . .[T]he mistakes that were made on [the *Columbia* mission] are not isolated failures, but are indicative of systemic flaws that existed prior to the accident.. . .[A successful safety process] demands a more independent status than NASA has ever been willing to give its safety organizations, despite the recommendations of numerous outside experts over nearly two decades[.]"

According to the CAIB Report, NASA's current approach to safety and mission assurance "calls for centralized policy and oversight at Headquarters and decentralized execution of safety programs at the enterprise, program, and project levels." Under the existing organizational rubric, "safety is the responsibility of program and project managers" who are given flexibility "to organize safety efforts as they see fit."

To remedy the current organization deficiencies, the primary CAIB recommendation on organization calls on NASA to "establish an independent Technical Engineering Authority" that would be "responsible for technical requirements and all waivers to them" and that would be "funded directly from NASA Headquarters, and should have no connection to or responsibility for schedule or program cost." The CAIB's fundamental goal is to separate the responsibility for safety from the Shuttle program's responsibility for cost and schedule. The current NASA structure, in which the Shuttle program itself is ultimately responsible for cost, schedule and safety inevitably leads to "blind spots"—serious safety problems that are not properly analyzed or addressed, the CAIB concluded. The CAIB did not specify precisely how NASA should be reorganized to implement its recommendations, leaving that up to the agency.

While the CAIB report does not label the implementation of a new organizational structure as a "return to flight" requirement, the report does say that NASA must "prepare a detailed plan for defining, establishing, transitioning and implementing an independent Technical Engineering Authority, independent safety program, and a reorganized Space Shuttle Integration Office" prior to returning to flight.

NASA is in the process of preparing such a plan. Administrator Sean O'Keefe has tasked the Associate Administrator for Safety and Mission Assurance, Bryan O'Connor, with coming up with a proposed reorganization plan. O'Connor has circulated a "white paper" outlining his ideas for reorganization among NASA staff. Before being implemented, any reorganization plan will be reviewed both by the Stafford-Covey Task Force (the task force of outside experts set up by O'Keefe to evaluate return-to-flight activities, which is headed by former astronauts Tom Stafford and Richard Covey) and by the Space Flight Leadership Council, which comprises top NASA officials. NASA is also in the process of setting up a new NASA Engineering and Safety Center (NESC), which would be able to "independently" review aspects of programs. It is not clear how the NESC would relate to a new Independent Technical Engineering Authority, but Admiral Harold Gehman, the chairman of the CAIB, has testified that the NESC does not, by itself, fulfill the CAIB's recommendations related to organization.

Model safety organizations

The CAIB Report cites three examples of organizations with successful safety programs and practices that could be models for NASA: the United States Navy's Naval Reactors and SUBSAFE programs and the Aerospace Corporation's independent launch verification process and mission assurance program for the U.S. Air Force.

The Naval Reactors program is a joint Navy/Department of Energy organization responsible for all aspects of Navy nuclear propulsion, including research, design, testing, training, operation, and maintenance of nuclear propulsion plants on-board Navy ships and submarines. The Naval Reactors program is structurally independent of the operational program that it serves. Although the naval fleet is ultimately responsible for day-to-day operations and maintenance, those operations occur within parameters independently established by the Naval Reactors program. In addition to its independence, the Naval Reactors program has certain features

that might be emulated by NASA, including an insistence on airing minority opinions and planning for worst case scenarios, a requirement that contractor technical requirements are documented in peer reviewed formal written correspondence, and a dedication to relentless training and retraining of its engineering and safety personnel.

SUBSAFE is a program that was initiated by the Navy to identify critical changes in submarine certification requirements and to verify the readiness and safety of submarines. The SUBSAFE program was initiated in the wake of the *USS Thresher* nuclear submarine accident in 1963. Until SUBSAFE independently verifies that a submarine has complied with SUBSAFE design and process requirements, its operating depth and maneuvers are limited. The SUBSAFE requirements are clearly documented and achievable, and rarely waived. Program mangers are not permitted to "tailor" requirements without approval from SUBSAFE. Like the Naval Reactors program, the SUBSAFE program is structurally independent from the operational program that it serves. Likewise, SUBSAFE stresses training and retraining of its personnel based on "lessons learned," and appears to be relatively immune from budget pressures.

The Aerospace Corporation operates as a Federally Funded Research and Development Center that independently verifies safety and readiness for space launches by the United States Air Force. As a separate entity altogether from the Air Force, Aerospace conducts system design and integration, verifies launch readiness, and provides technical oversight of contractors. Aerospace is indisputably independent and is not subject to schedule or cost pressures.

According to the CAIB, the Navy and Air Force programs have "invested in redundant technical authorities and processes to become reliable." Specifically, each of the programs allows technical and safety engineering organizations (rather than the operational organizations that actually deploy the ships, submarines and planes) to "own" the process of determining, maintaining, and waiving technical requirements. Moreover, each of the programs is independent enough to avoid being influenced by cost, schedule, or mission-accomplishment goals. Finally, each of the programs provides its safety and technical engineering organizations with a powerful voice in the overall organization. According to the CAIB, the Navy and Aerospace programs "yield valuable lessons for [NASA] to consider when redesigning its organization to increase safety."

4. Witnesses

First Panel

a. Admiral Frank L. "Skip" Bowman, United States Navy (USN), is the Director of the Naval Nuclear Propulsion (Naval Reactors) Program. In this capacity, Admiral Bowman is responsible for the program that oversees the design, development, procurement, operation, and maintenance of all the nuclear propulsion plants powering the Navy's fleet of nuclear warships. Admiral Bowman is a graduate of Duke University and the Massachusetts Institute of Technology.

b. Rear Admiral Paul Sullivan, USN, is the Deputy Commander for Ship Design Integration and Engineering for the Naval Sea Systems Command, which is the authority for the technical requirements of the SUBSAFE program. Admiral Sullivan is a graduate of the U.S. Naval Academy and the Massachusetts Institute of Technology.

c. Mr. Ray F. Johnson is the Vice President for Space Launch Operations for the Aerospace Corporation, located in El Segundo, California. Mr. Johnson is responsible for Aerospace's support for all Air Force space launch programs, including Aerospace's certification reviews prior to launch. Mr. Johnson holds a B.S. degree in mechanical engineering from the University of California at Berkeley and an MBA from the University of Chicago.

d. Ms. Deborah L. Grubbe is the Corporate Director for Safety and Health at Dupont. In this capacity, Ms. Grubbe is tasked with leading new initiatives in global safety and occupational health for Dupont. Ms. Grubbe and is a past director of DuPont Nonwovens, where she was accountable for manufacturing, engineering, and safety. Ms. Grubbe holds a B.S. degree in chemical engineering from Purdue University and a Certificate of Post-Graduate Study in chemical engineering from Cambridge University.

Second Panel

Admiral Harold Gehman, Jr., USN (retired), chaired the *Columbia* Accident Investigation Board.

5. Attachment

Excerpt from the *Columbia* Accident Investigation Board Report, Volume I (August 2003), Chapter 7, Section 7.3 (pp. 182–184).

can the Program do about these difficulties? The Board considered three alternatives. First, the Board could recommend that NASA follow traditional paths to improving safety by making changes to policy, procedures, and processes. These initiatives could improve organizational culture. The analysis provided by experts and the literature leads the Board to conclude that although reforming management practices has certain merits, it also has critical limitations. Second, the Board could recommend that the Shuttle is simply too risky and should be grounded. As will be discussed in Chapter 9, the Board is committed to continuing human space exploration, and believes the Shuttle Program can and should continue to operate. Finally, the Board could recommend a significant change to the organizational structure that controls the Space Shuttle Program's technology. As will be discussed at length in this chapter's conclusion, the Board believes this option has the best chance to successfully manage the complexities and risks of human space flight.

7.3 ORGANIZATIONAL CAUSES: EVALUATING BEST SAFETY PRACTICES

Many of the principles of solid safety practice identified as crucial by independent reviews of NASA and in accident and risk literature are exhibited by organizations that, like NASA, operate risky technologies with little or no margin for error. While the Board appreciates that organizations dealing with high-risk technology cannot sustain accident-free performance indefinitely, evidence suggests that there are effective ways to minimize risk and limit the number of accidents.

In this section, the Board compares NASA to three specific examples of independent safety programs that have strived for accident-free performance and have, by and large, achieved it: the U.S. Navy Submarine Flooding Prevention and Recovery (SUBSAFE), Naval Nuclear Propulsion (Naval Reactors) programs, and the Aerospace Corporation's Launch Verification Process, which supports U.S. Air Force space launches.[19] The safety cultures and organizational structure of all three make them highly adept in dealing with inordinately high risk by designing hardware and management systems that prevent seemingly inconsequential failures from leading to major accidents. Although size, complexity, and missions in these organizations and NASA differ, the following comparisons yield valuable lessons for the space agency to consider when re-designing its organization to increase safety.

Navy Submarine and Reactor Safety Programs

Human space flight and submarine programs share notable similarities. Spacecraft and submarines both operate in hazardous environments, use complex and dangerous systems, and perform missions of critical national significance. Both NASA and Navy operational experience include failures (for example, USS *Thresher*, USS *Scorpion*, *Apollo 1* capsule fire, *Challenger*, and *Columbia*). Prior to the *Columbia* mishap, Administrator Sean O'Keefe initiated the NASA/Navy Benchmarking Exchange to compare and contrast the programs, specifically in safety and mission assurance.[20]

The Navy SUBSAFE and Naval Reactor programs exercise a high degree of engineering discipline, emphasize total responsibility of individuals and organizations, and provide redundant and rapid means of communicating problems to decision-makers. The Navy's nuclear safety program emerged with its first nuclear-powered warship (USS *Nautilus*), while non-nuclear SUBSAFE practices evolved from from past flooding mishaps and philosophies first introduced by Naval Reactors. The Navy lost two nuclear-powered submarines in the 1960s – the USS *Thresher* in 1963 and the *Scorpion* 1968 – which resulted in a renewed effort to prevent accidents.[21] The SUBSAFE program was initiated just two months after the *Thresher* mishap to identify critical changes to submarine certification requirements. Until a ship was independently recertified, its operating depth and maneuvers were limited. SUBSAFE proved its value as a means of verifying the readiness and safety of submarines, and continues to do so today.[22]

The Naval Reactor Program is a joint Navy/Department of Energy organization responsible for all aspects of Navy nuclear propulsion, including research, design, construction, testing, training, operation, maintenance, and the disposition of the nuclear propulsion plants onboard many Naval ships and submarines, as well as their radioactive materials. Although the naval fleet is ultimately responsible for day-to-day operations and maintenance, those operations occur within parameters established by an entirely independent division of Naval Reactors.

The U.S. nuclear Navy has more than 5,500 reactor years of experience without a reactor accident. Put another way, nuclear-powered warships have steamed a cumulative total of over 127 million miles, which is roughly equivalent to over 265 lunar roundtrips. In contrast, the Space Shuttle Program has spent about three years on-orbit, although its spacecraft have traveled some 420 million miles.

Naval Reactor success depends on several key elements:

- Concise and timely communication of problems using redundant paths
- Insistence on airing minority opinions
- Formal written reports based on independent peer-reviewed recommendations from prime contractors
- Facing facts objectively and with attention to detail
- Ability to manage change and deal with obsolescence of classes of warships over their lifetime

These elements can be grouped into several thematic categories:

- **Communication and Action:** Formal and informal practices ensure that relevant personnel at all levels are informed of technical decisions and actions that affect their area of responsibility. Contractor technical recommendations and government actions are documented in peer-reviewed formal written correspondence. Unlike NASA, PowerPoint briefings and papers for technical seminars are not substitutes for completed staff work. In addition, contractors strive to provide recommendations

based on a technical need, uninfluenced by headquarters or its representatives. Accordingly, division of responsibilities between the contractor and the Government remain clear, and a system of checks and balances is therefore inherent.

- **Recurring Training and Learning From Mistakes:** The Naval Reactor Program has yet to experience a reactor accident. This success is partially a testament to design, but also due to relentless and innovative training, grounded on lessons learned both inside and outside the program. For example, since 1996, Naval Reactors has educated more than 5,000 Naval Nuclear Propulsion Program personnel on the lessons learned from the *Challenger* accident.[23] Senior NASA managers recently attended the 143rd presentation of the Naval Reactors seminar entitled "The Challenger Accident Re-examined." The Board credits NASA's interest in the Navy nuclear community, and encourages the agency to continue to learn from the mistakes of other organizations as well as from its own.

- **Encouraging Minority Opinions:** The Naval Reactor Program encourages minority opinions and "bad news." Leaders continually emphasize that when no minority opinions are present, the responsibility for a thorough and critical examination falls to management. Alternate perspectives and critical questions are always encouraged. In practice, NASA does not appear to embrace these attitudes. Board interviews revealed that it is difficult for minority and dissenting opinions to percolate up through the agency's hierarchy, despite processes like the anonymous NASA Safety Reporting System that supposedly encourages the airing of opinions.

- **Retaining Knowledge:** Naval Reactors uses many mechanisms to ensure knowledge is retained. The Director serves a minimum eight-year term, and the program documents the history of the rationale for every technical requirement. Key personnel in Headquarters routinely rotate into field positions to remain familiar with every aspect of operations, training, maintenance, development and the workforce. Current and past issues are discussed in open forum with the Director and immediate staff at "all-hands" informational meetings under an in-house professional development program. NASA lacks such a program.

- **Worst-Case Event Failures:** Naval Reactors hazard analyses evaluate potential damage to the reactor plant, potential impact on people, and potential environmental impact. The Board identified NASA's failure to adequately prepare for a range of worst-case scenarios as a weakness in the agency's safety and mission assurance training programs.

SUBSAFE

The Board observed the following during its study of the Navy's SUBSAFE Program.

- SUBSAFE requirements are clearly documented and achievable, with minimal "tailoring" or granting of waivers. NASA requirements are clearly documented but are also more easily waived.

- A separate compliance verification organization independently assesses program management.[24] NASA's Flight Preparation Process, which leads to Certification of Flight Readiness, is supposed to be an independent check-and-balance process. However, the Shuttle Program's control of both engineering and safety compromises the independence of the Flight Preparation Process.

- The submarine Navy has a strong safety culture that emphasizes understanding and learning from past failures. NASA emphasizes safety as well, but training programs are not robust and methods of learning from past failures are informal.

- The Navy implements extensive safety training based on the *Thresher* and *Scorpion* accidents. NASA has not focused on any of its past accidents as a means of mentoring new engineers or those destined for management positions.

- The SUBSAFE structure is enhanced by the clarity, uniformity, and consistency of submarine safety requirements and responsibilities. Program managers are not permitted to "tailor" requirements without approval from the organization with final authority for technical requirements and the organization that verifies SUBSAFE's compliance with critical design and process requirements.[25]

- The SUBSAFE Program and implementing organization are relatively immune to budget pressures. NASA's program structure requires the Program Manager position to consider such issues, which forces the manager to juggle cost, schedule, and safety considerations. Independent advice on these issues is therefore inevitably subject to political and administrative pressure.

- Compliance with critical SUBSAFE design and process requirements is *independently verified* by a highly capable centralized organization that also "owns" the processes and monitors the program for compliance.

- Quantitative safety assessments in the Navy submarine program are deterministic rather than probabilistic. NASA does not have a quantitative, program-wide risk and safety database to support future design capabilities and assist risk assessment teams.

Comparing Navy Programs with NASA

Significant differences exist between NASA and Navy submarine programs.

- **Requirements Ownership (Technical Authority):** Both the SUBSAFE and Naval Reactors' organizational

approach separates the technical and funding authority from program management in safety matters. The Board believes this separation of authority of program managers – who, by nature, must be sensitive to costs and schedules – and "owners" of technical requirements and waiver capabilities – who, by nature, are more sensitive to safety and technical rigor – is crucial. In the Naval Reactors Program, safety matters are the responsibility of the technical authority. They are not merely relegated to an independent safety organization with oversight responsibilities. This creates valuable checks and balances for safety matters in the Naval Reactors Program technical "requirements owner" community.

- **Emphasis on Lessons Learned:** Both Naval Reactors and the SUBSAFE have "institutionalized" their "lessons learned" approaches to ensure that knowledge gained from both good and bad experience is maintained in corporate memory. This has been accomplished by designating a central technical authority responsible for establishing and maintaining functional technical requirements as well as providing an organizational and institutional focus for capturing, documenting, and using operational lessons to improve future designs. NASA has an impressive history of scientific discovery, but can learn much from the application of lessons learned, especially those that relate to future vehicle design and training for contingencies. NASA has a broad Lessons Learned Information System that is strictly voluntary for program/project managers and management teams. Ideally, the Lessons Learned Information System should support overall program management and engineering functions and provide a historical experience base to aid conceptual developments and preliminary design.

The Aerospace Corporation

The Aerospace Corporation, created in 1960, operates as a Federally Funded Research and Development Center that supports the government in science and technology that is critical to national security. It is the equivalent of a $500 million enterprise that supports U.S. Air Force planning, development, and acquisition of space launch systems. The Aerospace Corporation employs approximately 3,200 people including 2,200 technical staff (29 percent Doctors of Philosophy, 41 percent Masters of Science) who conduct advanced planning, system design and integration, verify readiness, and provide technical oversight of contractors.[26]

The Aerospace Corporation's independent launch verification process offers another relevant benchmark for NASA's safety and mission assurance program. Several aspects of the Aerospace Corporation launch verification process and independent mission assurance structure could be tailored to the Shuttle Program.

Aerospace's primary product is a formal verification letter to the Air Force Systems Program Office stating a vehicle has been *independently* verified as ready for launch. The verification includes an independent General Systems Engineering and Integration review of launch preparations by Aerospace staff, a review of launch system design and payload integration, and a review of the adequacy of flight and ground hardware, software, and interfaces. This "concept-to-orbit" process begins in the design requirements phase, continues through the formal verification to countdown and launch, and concludes with a post-flight evaluation of events with findings for subsequent missions. Aerospace Corporation personnel cover the depth and breadth of space disciplines, and the organization has its own integrated engineering analysis, laboratory, and test matrix capability. This enables the Aerospace Corporation to rapidly transfer lessons learned and respond to program anomalies. Most importantly, Aerospace is uniquely independent and is not subject to any schedule or cost pressures.

The Aerospace Corporation and the Air Force have found the independent launch verification process extremely valuable. Aerospace Corporation involvement in Air Force launch verification has significantly reduced engineering errors, resulting in a 2.9 percent "probability-of-failure" rate for expendable launch vehicles, compared to 14.6 percent in the commercial sector.[27]

Conclusion

The practices noted here suggest that responsibility and authority for decisions involving technical requirements and safety should rest with an independent technical authority. Organizations that successfully operate high-risk technologies have a major characteristic in common: they place a premium on safety and reliability by structuring their programs so that technical and safety engineering organizations own the process of determining, maintaining, and waiving technical requirements with a voice that is equal to yet independent of Program Managers, who are governed by cost, schedule and mission-accomplishment goals. The Naval Reactors Program, SUBSAFE program, and the Aerospace Corporation are examples of organizations that have invested in redundant technical authorities and processes to become highly reliable.

7.4 ORGANIZATIONAL CAUSES: A BROKEN SAFETY CULTURE

Perhaps the most perplexing question the Board faced during its seven-month investigation into the *Columbia* accident was "How could NASA have missed the signals the foam was sending?" Answering this question was a challenge. The investigation revealed that in most cases, the Human Space Flight Program is extremely aggressive in reducing threats to safety. But we also know – in hindsight – that detection of the dangers posed by foam was impeded by "blind spots" in NASA's safety culture.

From the beginning, the Board witnessed a consistent lack of concern about the debris strike on *Columbia*. NASA managers told the Board "there was no safety-of-flight issue" and "we couldn't have done anything about it anyway." The investigation uncovered a troubling pattern in which Shuttle Program management made erroneous assumptions about the robustness of a system based on prior success rather than on dependable engineering data and rigorous testing.

Chairman BOEHLERT. We might as well start. We thank you for being punctual, and I tried very hard to be punctual, too.

I want to welcome everyone to today's hearing, which concerns one of the most critical recommendations of the *Columbia* Accident Investigation Board. The CAIB was clear and on-target in citing organizational deficiencies as a leading cause of the *Columbia* accident. It was also clear and on-target in calling for the establishment of a new Independent Technical Engineering Authority and of a truly independent safety organization. And in both instances, I stress the word "independent".

In both its conclusions and its recommendations on organization, the *Columbia* Accident Investigation Board was, unfortunately, able to follow a well-worn path. The Rogers Commission and the Shuttle Independent Assessment Team, among others, had made similar recommendations. They all apparently fell on deaf ears. This must not be allowed to happen again.

NASA Administrator Sean O'Keefe is to be applauded for deciding that the reorganization of NASA should occur before return to flight, setting a more ambitious schedule than that called for by the CAIB. He should also be congratulated for recognizing NASA's organizational deficiencies before the *Columbia* accident, which led him to initiate the so-called "benchmarking studies" comparing NASA with the Navy, something with which he is most familiar.

But, of course, undertaking the right studies and setting the right schedule is not enough. NASA must actually come up with the right reorganization plan and make sure that it is taken to heart.

The CAIB did not dictate exactly how NASA should carry out its recommendations, so NASA is now in the process of drawing up its plans, and this committee will have to review those plans with a fine-tooth comb.

The purpose of today's hearing is to help give us the background to do just that. We will hear from organizations that the CAIB cited as possible models for NASA to follow and from an industrial leader in safety. Obviously, there are differences among these models, and any one of them would have to be adapted to apply to NASA, but they all highlight characteristics of high-reliability organizations that NASA has been lacking. We will learn from Admiral Gehman precisely why and how the Navy and Air Force safety programs can be seen as models for NASA.

I have no doubt that this committee will have ample opportunity over the next year or so to put to use the information we gather today. As I noted earlier, NASA is just in the initial stages of putting together and organizational plan, and I have complete confidence that Administrator O'Keefe has taken the CAIB recommendations to heart.

But that said, I must note that I believe the initial organization ideas being circulated by NASA fall significantly short of the mark. We look forward to working with NASA as it continues to rework its plans.

Today's hearing, though, is not on any specific proposal. Rather, our goal today is to learn what has worked elsewhere and why and to start thinking how the experience of others could be put to work to help NASA.

This is one of the most important tasks facing this committee, and I am eager to hear from our witnesses today. And I want to thank you all for being resources.

[The prepared statement of Mr. Boehlert follows:]

PREPARED STATEMENT OF CHAIRMAN SHERWOOD BOEHLERT

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Chairman BOEHLERT. The gentleman from Texas, Mr. Hall.

Mr. HALL. Thank you, Mr. Chairman. I certainly join you in welcoming the panel and Admiral Bowman and Admiral Sullivan, Mr. Johnson, and Ms. Grubbe. And Admiral Gehman is to be here. I think he has a conflict right now, but he is to join us. We look forward to his input and his backing up the testimony that we are going to be hearing here and to thank him again for an excellent job that he did at a time when we really needed an excellent job to be done.

As we continue to address the recommendations of the panel, we now come to absolutely the most important part of it. We have talked about organizational items, and we were organized then, but we just weren't organized properly. And we need organizational

changes now. And that has got to be the thrust. The *Columbia* Accident Investigation Board, the CAIB, report devotes an entire chapter to the organizational causes of the accident. And in it, the CAIB makes three specific recommendations, and those are based on the CAIB's investigation of organizations that have had success in setting up and maintaining highly regarded safety procedures. They have had some experience and they know what they are doing. They know what they are recommending.

So three of the organizations represented by our witnesses here are specifically named by CAIB as examples of organizations, and I quote, "highly adept in dealing with inordinately high risk by designing hardware and management systems that prevent seemingly inconsequential failure from leading to major disasters." And you almost have to read that and read it again to really get the full impact of it. But we want to hear from each of you about the characteristics of your approaches to safety that you think are important for NASA to adopt.

However, setting up the right organizational structure is only part of the job. Ensuring that the organization carries through on safe practices is equally important. That is where independent oversight can play a valuable role, and that is why the Chairman emphasizes independence, independence, independence. After the Apollo fire in 1968, Congress set up the Aerospace Safety Advisory Panel, ASAP, to provide that function for the agency. And in recent years, it has become apparent that NASA had not followed through on a number of the ASAP's constructive recommendations. As many of you know, the entire membership of ASAP resigned last month. And that is highly irregular. I can't even remember such an action ever occurring. I think we need to find out why they resigned and what we need to do to address their concerns.

One of the ASAP's recommendations concerned the need for a crew escape system for the Shuttle. And I think ASAP was exactly right on that. I would also note that the appendices to the CAIB report that were released this week make it clear that we can and we should be doing more to ensure crew survivability on the Shuttle. I don't understand why we can't. I am going to press—continue to press for NASA action on a crew escape system if the Shuttle is going to be flying for many more years. If it is going to be flying for another year, I want us to be underway at doing it. I would hate to have a tragedy at the end of this year and not have already launched a method for them to escape whether we are able to get that in place. It is just like Reagan's star wars. I don't think Russia ever knew if we had one in place or not, but I think it helped that we were on our way there. And the fact that we were working toward it gave us a lot electronically and even nationally defensewise. And it was worthwhile. It was worth what we spent for it.

So I—and I have another concern. Admiral Gehman has made the point in recent months that he is concerned about NASA not following through on the CAIB recommendations once the Shuttle returns to flight. I also share his concern. I think an independent group is needed to monitor NASA's implementation of the CAIB recommendations. One potential approach is contained in H.R. 3219, a bill I recently introduced that directs the NASA Administrator to work with the National Academies of Science and Engi-

neering to establish such an independent oversight committee. It would report yearly to Congress for five years following the launch of the next Shuttle. As I have said, it is one potential approach. It is not the only one. There may be others. There may be a better way to go about ensuring continuing, independent oversight of NASA's Shuttle program. And I am open to suggestions. But I think we need to take action. I introduced that to get something kicked off, to get it going in the right direction. And if anybody can pick a better direction or a faster direction or a safer direction, then I am certainly interested in looking at. I—but I don't want CAIB's recommendations to wind up being ignored.

Well, I won't take any more time, Mr. Chairman, to discuss these issues. I know we all want to hear from the witnesses, very valuable witnesses, and people that are givers and not takers. You have had to prepare yourself to come here. You had to prepare yourself to know what you know and to do what you have done and then to share it with us. I appreciate it, and I know the Chair and this committee does.

And I yield back my time.

[The prepared statement of Mr. Hall follows:]

PREPARED STATEMENT OF REPRESENTATIVE RALPH M. HALL

Good morning. I want to join the Chairman in welcoming Admiral Bowman, Admiral Sullivan, Mr. Johnson, and Ms. Grubbe to our hearing. Admiral Gehman, welcome back to our committee. We again look forward to your comments.

As we continue to address the recommendations of the Gehman Panel, we now come to one of the most important areas—organizational changes. The *Columbia* Accident Investigation Board (CAIB) report devotes an entire chapter to the organizational causes of the accident. In it, the CAIB makes three specific recommendations. Those recommendations are based on the CAIB's investigation of organizations that have had success in setting up and maintaining highly regarded safety procedures.

Three of the organizations represented by our witnesses are specifically named by the CAIB as examples of organizations "highly adept in dealing with inordinately high risk by designing hardware and management systems that prevent seemingly inconsequential failure from leading to major disasters." We want to hear from each of you about the characteristics of your approaches to safety that you think are important for NASA to adopt.

However, setting up the right organizational structure is only part of the job. Ensuring that the organization carries through on safe practices is equally important. That's where independent oversight can play a valuable role. After the *Apollo* fire in 1968, Congress set up the Aerospace Safety Advisory Panel (ASAP) to provide that function for the agency. In recent years, it has become apparent that NASA has not followed through on a number of the ASAP's constructive recommendations. As many of you know, the entire membership of the ASAP resigned last month. I can't ever remember such an action occurring, and I think we need to find out *why* they resigned and what we need to do to address their concerns.

One of the ASAP's recommendations concerned the need for a crew escape system for the Shuttle. I think the ASAP was right. I'd also note that the appendices to the CAIB report that were released this week make it clear that we *can* and *should* be doing more to ensure crew survivability on the Shuttle. I'm going to continue to press for NASA action on a crew escape system if the Shuttle is going to be flying for many more years.

I have another concern. Admiral Gehman has made the point in recent months that he is concerned about NASA not following through on the CAIB recommendations once the Shuttle returns to flight. I share his concern. I think an independent group is needed to monitor NASA's implementation of the CAIB recommendations. One potential approach is contained in H.R. 3219, a bill I recently introduced that directs the NASA Administrator to work with the National Academies of Sciences and Engineering to establish such an independent oversight committee. It would report yearly to Congress for five years following the launch of the next shuttle. As I said, it is one potential approach. There may be other ways to go about ensuring continuing, independent oversight of NASA's Shuttle program, and I am open to

suggestions. But I think we need to take action soon so that the CAIB's recommendations don't wind up getting ignored.

Well, I will not take any more time to discuss these issues in my opening statement. I know we all want to hear from the witnesses, and I will continue this discussion during the question period.

I look forward to your testimony, and I yield back the balance of my time.

Chairman BOEHLERT. Thank you very much, Mr. Hall.

The gentleman from Tennessee, Mr. Gordon.

Mr. GORDON. Thank you, Mr. Chairman. I think that you sent us in a good direction with your earlier remarks, so I will be brief here. I want to also welcome the witnesses. It is my understanding that Admiral Gehman is on his way over from the Senate. And again, I want to thank him for his willingness to appear before the Committee again.

The *Columbia* Accident Investigation Board, which he chaired, raised a number of serious issues about the way NASA addressed safety in the Shuttle program. The Board came to the conclusion that should be of concern to all Members, namely, and I quote, "We are convinced that the management practices overseeing the Space Shuttle program were as much a cause of the accident as the foam that struck the left wing." To its credit, the Board did not simply highlight the problem. It also tried to offer some suggestions on how NASA might address the management issue.

Today, we are going to hear from some non-NASA organizations that the Board thinks may have some lessons learned for NASA. I look forward to their testimony. In particular, I hope that we can—or that they can offer the Committee some benchmarks by which we can judge NASA's responses to the Board's organizational recommendations.

Beyond that, Mr. Chairman, I hope that this hearing will be just a starting point for our examination of these issues. I hope that we will look at additional models of safety and organizations for insights that they might offer. For example, I think that we should look at how NASA and DOD handled experimental flight testing programs at the Dryden Research Center and Edwards Air Force Base.

I also think that it might be worth taking a look—a closer look at the Russian human space flight program. As I understand it, the Russians haven't had a space flight fatality since 1971, or more than 30 years ago. We might also benefit from the examination of how NASA handled safety in the earlier years, that is during the Apollo moon-landing program. Apollo was an extremely challenging program that may have lessons for us to learn today, also.

And finally, I want to support Mr. Hall's concerns and comments. I was also very concerned about the mass resignation of the Aerospace Safety Panel. ASAP members, I think we need to hear from them and hear more about why they resigned and what they feel like is necessary for their independence.

So there is a lot to cover today, and once again, thank you, Mr. Chairman, for bringing us together for this important meeting and I am glad the witnesses are giving their time today.

Chairman BOEHLERT. Thank you very much, Mr. Gordon and Mr. Hall.

[The prepared statement of Mr. Rohrabacher follows:]

PREPARED STATEMENT OF REPRESENTATIVE DANA ROHRABACHER

Mr. Chairman, your leadership has enabled this committee to carefully deliberate on the root causes that contributed to the *Columbia* Space Shuttle accident and critical issues surrounding the future of our civil space program in the wake of this tragedy.

Admiral Gehman and his colleagues found that overconfidence and an overly bureaucratic nature dominated NASA's historical decision-making of Shuttle Program managers. Although NASA claims it has made safety a high priority within the Space Shuttle Program, "blind spots" inherent in its culture impeded its ability to detect risks posed by something as simple as form.

NASA must get its house in order before it attempts to meet the challenge of space exploration. Our witnesses will provide us insight on how their organizations apply best practices for reducing the likelihood of accidents. Let's hope that what we learn today is useful for getting NASA on the path of recovery tomorrow.

Thank you Mr. Chairman.

[The prepared statement of Mr. Costello follows:]

PREPARED STATEMENT OF REPRESENTATIVE JERRY F. COSTELLO

Good morning. I want to thank the witnesses for appearing before our committee to discuss the organizational and management issues confronting NASA in the aftermath of the Space Shuttle *Columbia* accident. Today's hearing serves has an opportunity for Congress to gain a better understanding of the *Columbia* Accident Investigation Board (CAIB) recommendations and the successful safety programs of the organizations represented at this hearing so as to have an informed basis for judging whether NASA is in compliance with the CAIB recommendations.

I have been concerned with the Safety and Health regulation structure used by the DOE civilian labs. My colleague, Congressman Ken Calvert, has worked with me to introduce a bill ending DOE's self-regulation and opening the civilian labs up to regulation by OSHA and the NRC. The Jet Propulsion Laboratory (JPL) has been drawn into this discussion inadvertently due to its inclusion in the DOE 2002 Best Practices Study. That report, coupled with reviews done by the General Accounting Office, draws attention to the relative efficiency of JPL's management processes and provides a snapshot for what we would like to see at the civilian labs.

The same can be said about the Naval Nuclear Propulsion Program, the SUBSAFE program, and Aerospace Corporation in relation to NASA and evaluating best safety practices. You each represent organizations that have been identified as leaders in safety. The CAIB report recommends that NASA establish an independent Technical Engineering Authority that is responsible for all technical requirements and waivers to them. Further, the CAIB's fundamental goal in establishing this independent body is to separate the responsibility for safety from the Shuttle's program responsibility for cost and schedule.

I am interested to know if each of your organizations has an independent technical engineering authority or something similar and how it is independent from other elements of the organization, funded and staffed. Further, I am interested to know from Admiral Gehman how he and CAIB view the role of the Shuttle program manager in light of the CAIB recommendations.

I welcome our panel of witnesses and look forward to their testimony.

[The prepared statement of Ms. Johnson follows:]

PREPARED STATEMENT OF REPRESENTATIVE EDDIE BERNICE JOHNSON

Thank you, Mr. Chairman. I would like to thank you for calling this hearing today, and I would also like to thank our witnesses for agreeing to appear here today to answer our questions.

Today we are here to discuss issues concerning organization and management at the National Aeronautics and Space Administration (NASA).

At the end of the past summer, the final report of the *Columbia* Accident Investigation Board (CAIB) was released. While much of it focused on the technical causes, there was also a substantial emphasis on poor decisions and other organizational issues that may have led to the accident. Included in this report are communications about how repeated foam strikes on the Shuttle became damaged, as well as communications and decision-making issues among engineers and managers while the Shuttle was in orbit. These types of mistakes are entirely too costly.

We are now seeing the warning signs that show that NASA is an agency in trouble. The *Columbia* Accident Investigation Board sharply criticized NASA's safety

and management procedures. With problems escalating rather than abating, NASA still seems ready to put the mission ahead of an abundance of caution. What could be the disastrous affects if the Space Station is not being properly maintained and supplied, increasing the risk to its crew? In this environment, if senior safety officials cannot halt the launch of a replacement crew to a deteriorating Space Station, who at NASA can and would abort a dangerous mission?

We must put forth a more concerted effort to protect the safety of our astronauts.

It was over 40 years ago that this nation's leaders in human space travel were given the foresight to recognize the importance of space exploration. It is my hope that NASA will continue this exploration, with the intent of making safety first in all of their endeavors.

[The prepared statement of Ms. Jackson Lee follows:]

PREPARED STATEMENT OF REPRESENTATIVE SHEILA JACKSON LEE

Mr. Chairman,

Thank you for calling yet another critical hearing in this series to ensure that we in Congress are doing all we can do to help NASA get back on track to fulfilling its vital mission in Space. I have been pleased by the bipartisan spirit here and in the Space Subcommittee since February, when we lost the Shuttle *Columbia* and her brave crew. Fulfilling the call of the Gehman Board and changing the culture at NASA will take hard work, creativity, and good ideas from both sides of the aisle.

But we do not need to re-invent the wheel. As was stated in the *Columbia* Accident Investigation Board Report, there are several excellent models of organizations that work in high-risk areas, and still maintain solid safety records. I thank the representatives from those groups for joining us today, to enlighten us on the management practices they use to ensure that safety is not an afterthought, but a top priority.

Working together, I hope we can draw from their experiences and craft policies for NASA that will ensure that Shuttles and the Space Station, as well as the spaceships of the future, are robust and reliable.

I am especially interested in their opinions on the role of whistleblower protections and retaliation prevention in promoting open dialogue and safety. After the *Columbia* Disaster, it was painful to hear from the CAIB that there were people at NASA—and not just some interns with naive notions—but experienced engineers, who had recognized the dangers, and tried to take prudent steps to get images that may have averted disaster. Those experts were ignored. That is truly painful to think about. The report gave great insight into the broken culture of safety at NASA that impeded the flow of critical information from engineers up to program managers. I quote: "Further, when asked by investigators why they were not more vocal about their concerns, Debris Assessment Team members opined that by raising contrary points of view about Shuttle mission safety, they would be singled out for possible ridicule by their peers."

That reaffirms to me that strong whistleblower protections do not just protect workers. They protect lines of communication and dialogue that prevent waste, fraud, and abuse, and, in this case, might have saved lives. I have been working with union representatives to develop a pathway within NASA, through which workers with serious concerns about the safety of a mission or the survivability of crew can go to express their opinions. That body will make sure that due attention is given to their concerns. After that, the same office will be charged with following the employee that came to them over time, to ensure that they are not harassed or retaliated against in any way.

Workers that think critically and act responsibly should be rewarded, not punished. Protecting such workers will send a signal to all workers that safety must always come before speed. I would like to hear the panelists' opinions of this approach.

I am also interested in their opinions of what proportion of their budgets are dedicated to safety and quality assurance. Budgets are tight these days, and many important programs are being cut. However, if we are going to continue our mission in space—as I believe we must—we need to spend the appropriate funds to protect our investments and our astronauts. How much will that cost?

I am also pleased to see Admiral Gehman here again to share his expertise and insights with us. I would like to continue the dialogue we started last month, exploring how we can ensure that the lessons we learn about how to make the Shuttle safer also carry over to the Space Station and other NASA programs. Recent revelations that the new Space Station crew was sent up against the will of senior medical personnel were disturbing. It was even more disturbing to hear that the internal

debates about hazards to the crew did not percolate up to the Administrator until a couple of days before flight—and never made it to us in Congress. I hope it is not business-as-usual at NASA. I would like to hear the Admiral's ideas on this matter.

I look forward to the discussion. Thank you.

Panel I

Chairman BOEHLERT. Let us get right to our panel.

The panel consists of: Admiral F.L. "Skip" Bowman, Director, Naval Nuclear Propulsion Program; Rear Admiral Paul E. Sullivan, Deputy Commander, Ship Design, Integration and Engineering, Naval Sea Systems Command; Ray F. Johnson, Vice President, Space Launch Operations, The Aerospace Corporation; and Ms. Deborah Grubbe, Corporate Director, Safety and Health, DuPont. Thank you all for your willingness to serve as resources for this committee. And as you will discover, we are going to listen in wrapped attention, because what you have to say is very important to us and—as we go about our very important work. And I would ask that you try to summarize your statement. The Chair is not going to be arbitrary. What you have to say is too darn important to confine it to 300 seconds, but that would be sort of a benchmark of five minutes or so, so that we will have ample time for a dialogue and an exchange so that we can learn. Thank you very much.

Admiral Bowman, you are first up.

STATEMENT OF ADMIRAL F.L. "SKIP" BOWMAN, DIRECTOR, NAVAL NUCLEAR PROPULSION PROGRAM, U.S. NAVY

Admiral BOWMAN. Mr. Chairman, Mr. Hall, Members of the Committee, thank you very much for the opportunity to testify today on the culture of safety that has allowed Naval Reactors to be successful for the last 55 years.

First, let me say that I wish the circumstances that brought me here were different. I am sure it is true with you, also. Obviously, the underlying reason I am here involves your oversight of NASA in the aftermath of the Space Shuttle *Columbia* tragedy.

I want to begin, then, by extending my sympathy to all of the families, colleagues, and friends of the *Columbia* crew. I must also tell you that although there has been, and continues to be, much public discussion of the tragedy, why it happened and what changes NASA should pursue, I do not know firsthand the details surrounding the accident nor am I an expert on spacecraft or the NASA organization. I am therefore not qualified to make judgments about the causes of the tragedy or to even suggest changes that NASA may implement to prevent our nation from suffering another terrible loss. However, I have studied, very carefully, the final report of the *Columbia* Accident Investigation Board, and I believe, therefore, that you might draw some useful thoughts from my testimony today.

I am often asked, Mr. Chairman, how it is that Naval Reactors has been able to maintain its impeccable safety record for these 55 years. Just last week, I participated in a conference that asked these same questions, commemorating the 50th anniversary of President Eisenhower's "Atoms for Peace" speech, which partially

addressed these very questions that I will address today. And many of the things that I have said then are applicable today.

Since Admiral Hyman Rickover began the Naval Reactors Program in 1948, we have insisted that the only way to operate our nuclear power plants, the only way to ensure safe operation generation after generation, is to embrace a system that ingrains in each operator a total commitment to safety, a pervasive, enduring devotions to a culture of safety and environmental stewardship.

To ensure the Program's success, as our record of safety clearly demonstrates, Admiral Rickover established these core values, which endure today. First, technical excellence and technical competence are absolutely required in our work. Because things do happen, especially at sea, we rely on a multi-layered defense against off-normal events. Our reactor designs and operating procedures are uncomplicated and conservative, and we build in redundancy. Next, we still, and always will, select the very best people we can find with the highest integrity and professional competence; then we rigorously train them and continually challenge them. Third, we require formality and discipline, and we insist on forceful backup from the very youngest sailor on board all of the way up through to the commanding officer. And fourth, every level of the Program must accept inescapable, cradle-to-grave responsibility for every aspect of nuclear power operations. These core values, among others, are what define our organizational culture. They are visible in everything we do and have done for the last 55 years.

Today, in my eighth year as Admiral Rickover's successor, the fourth director of Naval Reactors, I oversee the operation of 103 naval reactors, equaling the number of commercial reactors in this country. These reactors, powering U.S. Navy ships, are welcomed in more than 150 ports and more than 50 countries around the world.

That welcome access is primarily due to our safety record. Safety is embedded in our organization in every individual at every level. Put another way, we use the word "mainstreamed." Safety is mainstreamed. It is not a responsibility unique to a segregated safety department that then attempts to impose its oversight on the rest of the organization. Each individual is completely responsible for his or her component, his or her system, from cradle to grave and this drives two other vital aspects of the way we do business.

First, when solving a problem, we determine the range of technically acceptable answers first. Then we find out how to fit one of those solutions into our other constraints, specifically cost and schedule, without imposing any undue risk and without challenging the safety aspects of the technically acceptable answers. If we need more time or more money, we simply ask for it. Although we pride ourselves as stewards of the Government's resources, we don't let funding or schedules outweigh sound technical judgment.

Second, the decision-making process occasionally brings out dissenting or minority opinions. When this occurs, my staff presents the facts from both sides of the issues to me directly. Before a final decision is made, every opinion is aired. There is never any fear of reprisal for not agreeing with the proposed recommendation; rather, if there is not a minority opinion, I ask why not and solicit that

minority opinion, treat it with the same weight as the consensus view. If I determine that there is enough information to make a decision, then I make a decision. If more data are needed, then we get more data.

In the aftermath of Three Mile Island, the accident in 1979, Admiral Rickover was asked to testify before Congress in a context very similar to my appearance here today. In his testimony, he said the following: "Over the years, many people have asked me how I run the Naval Reactors Program so that they might find some benefit for their own work. I am always chagrined at the tendency of people to expect that I have a simple, easy gimmick that makes my program function. Any successful program functions as an integrated whole of many factors. Trying to select just one aspect as the key one will not work. Each element depends on all of the others."

I wholeheartedly agree with what Admiral Rickover said those years ago. As I said earlier, there is no magic formula. Safety must be in the mainstream.

Mr. Chairman, with your permission, I will submit a copy of my written testimony along with Admiral Rickover's 1979 testimony for the record. This testimony is very relevant, because it describes many of the same attributes and core values that I have discussed today, demonstrating that in fact these key elements of Naval Reactors are timeless and enduring. That testimony also details the continual training program for the nuclear-trained Fleet operators. I have taken the opportunity to update the statistics on the first four pages of Admiral Rickover's testimony to put them in perspective for today's real numbers. Also, with your permission, I will submit a copy of the Program's annual environmental, occupational radiation exposure, and occupational safety and health reports for the Committee's perusal.

Our basic organization responsibilities, and, most importantly, our core values have remained largely unchanged since Admiral Rickover founded Naval Reactors. These core values that I have discussed today are the foundation that have allowed our nuclear-powered ships to safely steam more than 128 million miles, equivalent to over 5,000 trips around the Earth, without a reactor accident, indeed, with no measurable negative impact on the environment or human health.

Thank you very much for allowing me to testify today.

[The prepared statement of Admiral Bowman follows:]

PREPARED STATEMENT OF ADMIRAL F.L. "SKIP" BOWMAN

Mr. Chairman and Members of this committee, thank you for giving me the opportunity to testify today on the subject of the culture of safety that has allowed Naval Reactors to be successful for the last 55 years.

But first, let me say that that I wish the circumstances that brought me here were different. Obviously, the underlying reason I'm here involves your oversight of NASA in the aftermath of the Space Shuttle *Columbia* tragedy. I want to begin, then, by extending my sympathy to all the families, colleagues, and friends of the *Columbia* crew. I must also tell you that although there has been and continues to be much public discussion of the tragedy—why it happened, what changes NASA should pursue, and others—I do not know first-hand the details surrounding the accident, nor am I an expert on spacecraft or the NASA organization. I therefore am not qualified to make judgments about the causes of the tragedy or to suggest changes that NASA may implement to prevent our nation from suffering another terrible loss. However, having studied the final report of the *Columbia* Accident In-

vestigation Board, I believe you may draw some useful conclusions from my testimony.

My area of expertise is the Naval Reactors Program (NR), so it's better for me to talk about that. Admiral Hyman G. Rickover set up NR in 1948 to develop nuclear propulsion for naval warships. Nuclear propulsion is vital to the Navy today for the reasons Admiral Rickover envisioned 55 years ago: it gives our warships high speed, virtually unlimited endurance, worldwide mobility, and unmatched operational flexibility. When applied to our submarines, nuclear propulsion also enables the persistent stealth that allows these warships to operate undetected for long periods in hostile waters, exercising their full range of capabilities.

In 1982, after almost 34 years as the Director of Naval Reactors, Admiral Rickover retired. Recognizing the importance of preserving the authority and responsibilities Admiral Rickover had established, President Reagan signed Executive Order 12344. The provisions of the executive order were later set forth in Public Laws 98–525 [1984] and 106–65 [1999]. The executive order and laws require that the Director, Naval Reactors, hold positions of decision-making authority within both the Navy and the Department of Energy (DOE). Because continuity and stature are vital, the director has the rank of four-star admiral within the Navy and Deputy Administrator within the Department of Energy's National Nuclear Security Administration and a tenure of eight years.

Through the Executive Order and these laws, the director has responsibility for all aspects of naval nuclear propulsion, specifically:

- Direct supervision of our single-purpose DOE laboratories, the Expended Core Facility, and our training reactors.
- Research, development, design, acquisition, procurement, specification, construction, inspection, installation, certification, testing, overhaul, refueling, operating practices and procedures, maintenance, supply support, and ultimate disposition of naval nuclear propulsion plants and components, plus any related special maintenance and service facilities.
- Training (including that which is conducted at the DOE training reactors), assistance and concurrence in the selection, training, qualification, and assignment of personnel reporting to the director and of personnel who supervise, operate, or maintain naval nuclear propulsion plants.
- Administration of the Naval Nuclear Propulsion Program, including oversight of Program support in areas such as security, nuclear safeguards and transportation, public information, procurement, logistics, and fiscal management.
- And finally, perhaps most relevant to this committee, I am responsible for the safety of the reactors and associated naval nuclear propulsion plants, and control of radiation and radioactivity associated with naval nuclear propulsion activities, including prescribing and enforcing standards and regulations for these areas as they affect the environment and the safety and health of workers, operators, and the general public.

For more than seven years, I have been the director, the third successor to Admiral Rickover. I am responsible for the safe operation of 103 nuclear reactors—the same number as there are commercial nuclear power reactors in the U.S. Roughly 40 percent of the Navy's major combatants are nuclear powered, including 10 of its 12 aircraft carriers plus 54 attack submarines, 16 ballistic missile submarines, and two former ballistic missile submarines being converted to SSGNs (guided missile submarines). Also included in these 103 reactors are four training reactors and the NR–1, a deep submersible research submarine. The contribution these ships and their crews make to the national defense and, more recently, to the Global War on Terrorism is remarkable. And the Program's safety record speaks for itself: these warships have steamed over 128 million miles since 1953 and are welcomed in over 150 ports of call in over 50 countries around the world.

Safety is the responsibility of everyone at every level in the organization. Safety is embedded across all organizations in the Program, from equipment suppliers, contractors, laboratories, shipyards, training facilities, and the Fleet to our Headquarters. Put another way, safety is *mainstreamed.* It is not a responsibility unique to a segregated safety department that then attempts to impose its oversight on the rest of the organization.

To clarify what I mean by mainstreaming, let me tell you a story from my days as Chief of Naval Personnel. I was speaking to a large gathering of Army, Navy, Air Force, and Marine Corps military and civilian personnel at the Defense Equal Opportunity Management Institute. I startled the group by beginning with the phrase, "I'm here to tell you about plans to put you out of your jobs in a few years!" I explained that a worthwhile goal would be to have an organization that didn't

need specialists to monitor, enforce, and remind line management to do what's right. *That's* mainstreaming.

Our record of safety is the result of our making safety part of everything we do, day to day, not a magic formula. To achieve this organizational culture of safety in the mainstream, Admiral Rickover established certain *core values* in Naval Reactors that remain very visible today. I will discuss four of them: *People, Formality and Discipline, Technical Excellence and Competence,* and *Responsibility.*

PEOPLE

Admiral Rickover has been rightly credited with being an outstanding engineer and a gifted manager of technical matters. His other genius lay in finding and developing the right people to do extremely demanding jobs.

At NR, we still, and we always will, select the best people we can find, with the highest integrity and the willingness to accept complete responsibility over every aspect of nuclear-power operations. Admiral Rickover personally selected every member of his Headquarters staff and every naval officer accepted into the Program. This practice is still in place today, and I conduct these interviews and make the final decision myself.

It doesn't end there. After we hire the best men and women, the training they need to be successful begins immediately. All members of my technical staff undergo an indoctrination course that occupies their first several months at Headquarters. Next, they spend two weeks at one of our training reactors, learning about the operation of the reactor and the training our Fleet sailors are undergoing. This is experience with an actual, operating reactor plant, not a simulation or a PowerPoint presentation—and it is an important experience. It gives them an understanding that the work they do affects the lives of the sailors directly, while they perform the Navy's vital national defense role. This helps reinforce the tenet that the components and systems we provide must perform when needed.

Shortly after they return from the training reactor, they spend six months at one of our DOE laboratories for an intensive, graduate-level course in nuclear engineering. Once that course is complete, they spend three weeks at a nuclear-capable shipyard, observing production work and work controls. Finally, they return to Headquarters and are assigned to work in one of our various technical jobs. During the next six months, they attend a series of seminars, covering broad technical and regulatory matters, led by the most experienced members of my staff.

At Headquarters, there is a continued emphasis on professional development as we typically provide training courses that are open to the entire staff each month on various topics, technical and non-technical. In particular, we have many training sessions on lessons we've learned—trying to learn from mistakes that we, or others, have made in order to prevent similar mistakes from recurring.

Throughout their careers, the members of my staff are continually exposed to the end product, spending time on the waterfront, at the shipyards, in the laboratories, at the vendor sites, or interacting directly with the Fleet. My staff audits nuclear shipyards, vendors, training facilities, laboratories, and the ships to validate that our expectations are met. In addition, we receive constant feedback from the Fleet by several means. When a nuclear-powered ship returns from deployment, my staff and I are briefed on the missions the ship performed and any significant issues concerning the propulsion plant. Additionally, I have a small cadre of Fleet-experienced, nuclear-trained officers at Headquarters who, like me, bring operational expertise and perspective to the table.

My Headquarters staff is very small, comprised of about 380 people, including administrative and support personnel. We are also an extremely "flat" organization. About 50 individuals report directly to me, including my Headquarters section heads, plus field representatives at shipyards, major Program vendors, and the laboratories. Included in this is a small section of people responsible for Reactor Plant Safety Analysis. In an organization where safety is truly mainstreamed, one might ask why we have a section for Reactor Plant Safety Analysis. Here's why: they provide most of the liaison with other safety organizations (such as the NRC) to help ensure we are using best practices and to champion the use of those practices within my staff. They also maintain the documentation of procedures and upkeep of the modeling codes used in our safety analysis. Last, they provide one last layer that our mainstreamed safety practices are in fact working the way they should—an independent verification that we are not "normalizing" threats to safety. Thus, they are full-time safety experts who provide our corporate memory of what were past problems, what we have to do to maintain a consistent safety approach across all projects, and what we need to follow in civilian reactor safety practices.

Nearly all my Headquarters staff came to Naval Reactors right out of college. A great many of them spend their entire careers in the Program. For example, my sec-

tion heads, the senior managers who report directly to me, have an average of more than 25 years of Program experience. It is therefore not uncommon that a junior engineer working on the design of a component in a new reactor plant system will be responsible several years later for that same system during its service life.

Even though the focus of my testimony is on my Headquarters staff, I should also point out the importance of the Navy crews who operate our nuclear-powered warships. Again, I personally select the best people I can find and then train them constantly, giving them increasing challenges and responsibilities throughout their careers. My Headquarters staff and I oversee this training directly.

FORMALITY AND DISCIPLINE

Engineering for the long haul demands that decisions be made in a *formal and disciplined* manner. By "the long haul," I mean the cradle-to-grave life of a project, and even an individual reactor plant. Before a new class of ships (which may be in service for more than 50 years) is even put into service, we typically have already determined how we will perform maintenance—and refueling, if needed—and have considered eventual decommissioning and disposal of that ship. In the long life of a project, all requests and recommendations are received as formal correspondence. Resolution of issues is documented, as well. Whether we are approving a minor change to one of our technical manuals or resolving a major Fleet issue, the resolution will be clearly documented in formal correspondence.

That correspondence must have the documented concurrence of all parties within the Headquarters that have a stake in the matter. There are formal systems in place to track open commitments and agreements or dissents with proposed actions. I receive a copy of every recommended action prior to issue, a practice initiated by Admiral Rickover in July 1949; in fact, these recommendations are frequently discussed in detail and, when necessary, "cleared" with me prior to issue.

The 50 individuals who report directly to me inform me regularly and routinely of issues in their area of responsibility. In addition, commanding officers of nuclear-powered warships are required to report to me routinely on matters pertaining to the propulsion plant.

This organizational "flatness" streamlines the flow of information in both directions—allowing me to ensure that the guidance I provide reaches everyone, while ensuring that my senior leaders and I receive timely information vital to making the right decisions.

In our ships and at our training reactors, we require formality and discipline. Detailed written procedures are in place for all aspects of operation. These procedures are based on over 50 years of ship operational experience, and they are followed to the letter, with what we call *verbatim*—but not blind—*compliance.* Independent auditing, coupled with critical self-assessments at all levels and activities, is virtually continuous to ensure that crews are trained and procedures are followed properly. We insist on forceful backup, from young sailor to commanding officer. We also insist that the only way to operate our nuclear power plants—the only way to ensure safe operation, generation after generation—is to embrace a system that ingrains in each operator a total commitment to safety: a pervasive, enduring commitment to a culture of safety and environmental stewardship.

TECHNICAL EXCELLENCE AND COMPETENCE

Technical excellence and competence are required in our work. Nearly all of my managers are technical people with either an engineering or science background. My job requires me to be qualified by reason of technical background and experience in naval nuclear propulsion. I am a qualified, nuclear-trained naval officer, having previously served in many operational billets, including commanding officer of a submarine and of a submarine tender that maintains nuclear ships. It is crucial that the people making decisions understand the technology they are managing and the consequences of their decisions. It is also important that much of the technical expertise reside within the Government organization that oversees the contractor work. This enables the Government to be a highly informed and demanding customer of contractor technology and services.

An important part of our technical effort is working on small problems to prevent bigger problems from occurring. The way we do this is to ask the hard questions on every issue: *What are the facts? How do you know? Who is responsible? Who else knows about the issue and what are they doing about it? What other ships and places could be affected? What is the plan? When will it be done? Is this within our design, test, and operational experience? What are the expected outcomes? What is the worst that could happen? What are the dissenting opinions?* When dealing with an issue that seems minor, these and other questions like them not only lead us to solving the current problem before it gets worse, but also help us prevent future problems.

As we look at the many potential solutions to a given problem, we determine the range of technically acceptable answers first. Then we find out how to fit one of those solutions into our other constraints, specifically cost and schedule, *without imposing any undue risk.* If we need more time or more money, we ask for it. Although we pride ourselves as stewards of the Government's resources, we do not let funding or schedule concerns outweigh sound technical judgment.

Occasionally, the decision-making process brings out dissenting opinions. When this occurs, my staff presents the facts from both sides of the issue to me directly. Before a final decision is made, every opinion is aired. There is never any fear of reprisal for not agreeing with the proposed recommendation; rather, we solicit and welcome the *minority opinion* and treat it with the same weight as the consensus view. If I determine there is enough information to make a decision, I decide. If more data are needed, we get more.

Because things do happen—especially at sea—we rely on a multi-layered defense against off-normal events. Our reactor designs and operating procedures are simple and conservative, and we build in redundancy to compensate for the risks involved and the operational environment. (For example, the pressurized water reactors are self-regulating: the reactor is designed to protect itself during normal operations or casualty situations.) The systems and components are rugged—they must be to withstand battle shock and still perform. In certain key systems, there are redundant components so that if one is unable to function, the other can take over.

RESPONSIBILITY

Admiral Rickover realized the importance of having total responsibility. He once said:

> Responsibility is a unique concept: it can only reside and inhere in a single individual. You may share it with others, but your portion is not diminished. You may delegate it, but it is still with you. You may disclaim it, but you cannot divest yourself of it. Even if you do not recognize it or admit its presence, you cannot escape it. If responsibility is rightfully yours, no evasion, or ignorance, or passing the blame can shift the burden to someone else. Unless you can point your finger at the person who is responsible when something goes wrong, then you have never had anyone really responsible.

His concept of total responsibility and ownership permeates NR at every level. He also realized that while the Navy designed and operated the ships, the Atomic Energy Commission (the forerunner of the Department of Energy) was responsible for the nuclear research and development—he would need to have authority within both activities. Hence, he forged a joint Navy/Atomic Energy Commission program having the requisite authority within each activity to carry out the cradle-to-grave responsibility for all aspects of naval nuclear propulsion, including safety.

CONCLUSION

In the aftermath of the Three Mile Island accident in 1979, Admiral Rickover was asked to testify before Congress in a context similar to my appearance before you today. In this testimony, he said:

> Over the years, many people have asked me how I run the Naval Reactors Program, so that they might find some benefit for their own work. I am always chagrined at the tendency of people to expect that I have a simple, easy gimmick that makes my program function. Any successful program functions as an integrated whole of many factors. Trying to select one aspect as the key one will not work. Each element depends on all the others.

I wholeheartedly agree. As I said earlier, there is no magic formula. Safety must be in the mainstream.

Mr. Chairman, with your permission, I will submit a copy of Admiral Rickover's 1979 testimony for the record. This testimony is relevant because it describes many of the same key attributes and core values I have discussed today—demonstrating that in fact, these key elements of Naval Reactors are timeless and enduring. That testimony also details the continual training program for the nuclear-trained Fleet operators I mentioned earlier. I have updated the statistics on the first four pages to make them current and placed them in parentheses beside the 1979 data. Also, with your permission, I will submit a copy of the Program's annual environmental, occupational radiation exposure, and occupational safety and health reports. *[Note: These items are located in Appendix 2: Additional Material for the Record.]*

Our basic organization, responsibilities, and, most important, our core values have remained largely unchanged since Admiral Rickover founded NR. These core values that I've discussed today are the foundation that have allowed our nuclear-powered

ships to safely steam more than 128 million miles, equivalent to over 5,000 trips around the Earth. . .without a reactor accident. . .indeed, with no measurable negative impact on the environment or human health.

Thank you for allowing me to testify before you today.

BIOGRAPHY FOR ADMIRAL FRANK LEE BOWMAN

United States Navy, Director, Naval Nuclear Propulsion

Admiral Frank L. "Skip" Bowman is a native of Chattanooga, Tenn. He was commissioned following graduation in 1966 from Duke University. In 1973 he completed a dual master's program in nuclear engineering and naval architecture/marine engineering at the Massachusetts Institute of Technology and was elected to the Society of Sigma Xi. Adm. Bowman has been awarded the honorary degree of Doctor of Humane Letters from Duke University. Admiral Bowman serves on two visiting committees at MIT (Ocean Engineering and Nuclear Engineering), the Engineering Board of Visitors at Duke University, and the Nuclear Engineering Department Advisory Committee at the University of Tennessee.

His early assignments included tours in USS Simon Bolivar (SSBN 641), USS Pogy (SSN 647), USS Daniel Boone (SSBN 629), and USS Bremerton (SSN 698). In 1983, Adm. Bowman took command of USS City Of Corpus Christi (SSN 705), which completed a seven-month circumnavigation of the globe and two special classified missions during his command tour. His crew earned three consecutive Battle Efficiency "E" awards. Adm. Bowman later commanded USS Holland (AS 32) from August 1988 to April 1990. During this period, the Holland crew was awarded two Battle Efficiency "E" awards.

Ashore, Adm. Bowman has served on the staff of Commander, Submarine Squadron Fifteen, in Guam; twice in the Bureau of Naval Personnel in the Submarine Policy and Assignment Division; as the SSN 21 Attack Submarine Program Coordinator on the staff of the Chief of Naval Operations; on the Chief of Naval Operations' Strategic Studies Group; and as Executive Assistant to the Deputy Chief of Naval Operations (Naval Warfare). In December 1991, he was promoted to flag rank and assigned as Deputy Director of Operations on the Joint Staff (J–3) until June 1992, and then as Director for Political-Military Affairs (J–5) until July 1994. Adm. Bowman served as Chief of Naval Personnel from July 1994 to September 1996.

Admiral Bowman assumed duties as Director, Naval Nuclear Propulsion, on 27 September 1996, and was promoted to his present rank on 1 October 1996. In this position, he is also Deputy Administrator for Naval Reactors in the National Nuclear Security Administration, Department of Energy.

Under his command, his crews have earned the Meritorious Unit Commendation (three awards), the Navy Battle Efficiency "E" Ribbon (five awards), the Navy Expeditionary Medal (two awards), the Humanitarian Service Medal (two awards), the Sea Service Deployment Ribbon (three awards), and the Navy Arctic Service Ribbon. His personal awards include the Defense Distinguished Service Medal, the Navy Distinguished Service Medal, the Legion of Merit (with three gold stars), and the Officier de l'Ordre National du Mérite from the Government of France.

Chairman BOEHLERT. Thank you very much for some very fine testimony. And without objection, your statement, in its entirety, along with the supplemental material, will be included in the record. And that will hold true for the testimony of all of our distinguished witnesses. We want everything you can give us, because we—that is how we learn. And thank you, Admiral, and congratulations, once again, for an outstanding program.

Admiral Sullivan.

STATEMENT OF REAR ADMIRAL PAUL E. SULLIVAN, DEPUTY COMMANDER, SHIP DESIGN, INTEGRATION AND ENGINEERING, NAVAL SEA SYSTEMS COMMAND, U.S. NAVY

Rear Admiral SULLIVAN. Good morning, Mr. Chairman, Mr. Hall, Members of the Committee. I would like to thank you for the opportunity to testify about the Submarine Safety Program, which we call in the Navy, SUBSAFE.

I serve as the Naval Sea Systems Command's Deputy Commander for Ship Design, Integration and Engineering. My organization is the authority for the technical requirements that underpin the SUBSAFE Program.

Mr. Chairman, I have submitted a written statement, which addresses the questions you raised about the SUBSAFE Program, and I will summarize that statement for you now.

On April 10, 1963, when engaged in a deep test dive, the *USS Thresher* was lost with 129 people on board. The loss of *Thresher* and her crew was a devastating event for the submarine community, the Navy, and the Nation.

Shortly after that tragedy, the SUBSAFE Program was created in June 1963. It established submarine design requirements, initial submarine safety certification requirements, and submarine safety certification continuity requirements.

The purpose of the SUBSAFE Program is to provide maximum reasonable assurance of watertight integrity and the ability of our submarines to recover from flooding. It is important to note that the SUBSAFE Program does not spread or dilute its focus beyond that purpose.

The heart of the Program is a combination of work discipline, material control, and documentation.

The SUBSAFE Program has been very successful, however, it has not been without problems. For example, in 1984 NAVSEA directed a thorough evaluation of the SUBSAFE Program to ensure that mandatory discipline had been maintained. As a result, the following year, in 1985, the Submarine Safety and Quality Assurance Division was established as an independent organization within NAVSEA to strengthen compliance with SUBSAFE requirements.

The SUBSAFE Program continues to adapt to the ever-changing construction and maintenance environments as well as new and evolving technologies as they become used on our submarines.

Safety is central to the culture of our entire Navy submarine community, including designers, builders, maintainers, and operators. The Navy's submarine safety culture is instilled through the following: first, clear, concise, non-negotiable requirements; second, multiple, structured audits; and third, annual training with strong, emotional lessons learned from past failures.

SUBSAFE certification is a disciplined process that lead to formal authorization for unrestricted operations on a submarine. Once a submarine is certified for unrestricted operation, we use three elements to maintain that certification. The first, the Re-entry Control Process, is used to control work within the SUBSAFE boundary and is the backbone of this certification continuity. The second, the Unrestricted Operation/Maintenance Requirement Program, is used to carry out periodic inspections and tests of critical systems, and that is the technical basis for continued unrestricted operations. Third, SUBSAFE audits are used to confirm compliance with SUBSAFE requirements. We use two primary types of audits. The first is a certification audit, and that audit examines the objective quality evidence, or paperwork, for an individual submarine to ensure that that submarine is satisfactory for unrestricted operations. Functional audits review the organizations that perform

SUBSAFE work to ensure that the organization complies with SUBSAFE requirements.

In addition to these formal NAVSEA audits, our field organizations and the Fleet are required to conduct their own similar internal audits. In fact, we also have the field activities audit the headquarters. We have some homework to do, for instance, from the most recent of those headquarters audits that was performed this summer.

The SUBSAFE Program has a formal organizational structure, which has key—three key elements: first, technical authority; second, program management; and third, the submarine safety and quality assurance. Each of these elements is organizationally independent and has the authority to stop the certification process until an identified issue has been satisfactorily resolved.

Our nuclear submarines require a highly competent and experienced technical workforce and constant vigilance to prevent complacency. Despite our past successes, mandated downsizing of our workforce has caused us to continually optimize our processes and to become more efficient while we maintain that culture of safety.

In conclusion, let me reiterate that since the inception of the SUBSAFE Program in 1963, the Navy has had a disciplined process that provides maximum reasonable assurance that our submarines are safe from flooding and can recover from a flooding incident. We have taken the lessons learned from the *Thresher* to heart, and we have them—made them a part of our submarine culture.

Thank you.

[The prepared statement of Rear Admiral Sullivan follows:]

PREPARED STATEMENT OF REAR ADMIRAL PAUL E. SULLIVAN

NAVAL SEA SYSTEMS COMMAND
SUBMARINE SAFETY (SUBSAFE) PROGRAM

Good Morning Chairman Boehlert, Ranking Member Hall and Members of the Committee.

Thank you for the opportunity to testify before this committee about the Submarine Safety Program, which the Navy calls SUBSAFE, and how it operates.

My name is RADM Paul Sullivan, USN. I serve as the Naval Sea System Command's Deputy Commander for Ship Design, Integration and Engineering, which is the authority for the technical requirements of the SUBSAFE Program.

To establish perspective, I will provide a brief history of the SUBSAFE Program and its development. I will then give you a description of how the program operates and the organizational relationships that support it. I am also prepared to discuss our NASA/Navy benchmarking activities that have occurred over the past year.

SUBSAFE PROGRAM HISTORY

On April 10, 1963, while engaged in a deep test dive, approximately 200 miles off the northeastern coast of the United States, the *USS THRESHER* (SSN–593) was lost at sea with all persons aboard—112 naval personnel and 17 civilians. Launched in 1960 and the first ship of her class, the *THRESHER* was the leading edge of U.S. submarine technology, combining nuclear power with a modern hull design. She was fast, quiet and deep diving. The loss of *THRESHER* and her crew was a devastating event for the submarine community, the Navy and the Nation.

The Navy immediately restricted all submarines in depth until an understanding of the circumstances surrounding the loss of the *THRESHER* could be gained.

A Judge Advocate General (JAG) Court of Inquiry was conducted, a *THRESHER* Design Appraisal Board was established, and the Navy testified before the Joint Committee on Atomic Energy of the 88th Congress.

The JAG Court of Inquiry Report contained 166 Findings of Fact, 55 Opinions, and 19 Recommendations. The recommendations were technically evaluated and incorporated into the Navy's SUBSAFE, design and operational requirements.

The *THRESHER* Design Appraisal Board reviewed the *THRESHER*'s design and provided a number of recommendations for improvements.

Navy testimony before the Joint Committee on Atomic Energy occurred on June 26, 27, July 23, 1963 and July 1, 1964 and is a part of the Congressional Record.

While the *exact* cause of the *THRESHER* loss is not known, from the facts gathered during the investigations, we do know that there were deficient specifications, deficient shipbuilding practices, deficient maintenance practices, and deficient operational procedures. Here's what we think happened:

- *THRESHER* had about 3000 silver-brazed piping joints exposed to full submergence pressure. During her last shipyard maintenance period 145 of these joints were inspected on a not-to-delay vessel basis using a new technique called Ultrasonic Testing. Fourteen percent of the joints tested showed substandard joint integrity. Extrapolating these test results to the entire population of 3000 silver-brazed joints indicates that possibly more than 400 joints on *THRESHER* could have been sub-standard. One or more of these joints is believed to have failed, resulting in flooding in the engine room.
- The crew was unable to access vital equipment to stop the flooding.
- Saltwater spray on electrical components caused short circuits, reactor shutdown, and loss of propulsion power.
- The main ballast tank blow system failed to operate properly at test depth. We believe that various restrictions in the air system coupled with excessive moisture in the system led to ice formation in the blow system piping. The resulting blockage caused an inadequate blow rate. Consequently, the submarine was unable to overcome the increasing weight of water rushing into the engine room.

The loss of *THRESHER* was the genesis of the SUBSAFE Program. In June 1963, not quite two months after *THRESHER* sank, the SUBSAFE Program was created. The SUBSAFE Certification Criterion was issued by BUSHIPS letter Ser 525–0462 of 20 December 1963, formally implementing the Program.

The Submarine Safety Certification Criterion provided the basic foundation and structure of the program that is still in place today. The program established:

- Submarine design requirements
- Initial SUBSAFE certification requirements with a supporting process, and
- Certification continuity requirements with a supporting process.

Over the next 11 years the submarine safety criterion underwent 37 changes. In 1974, these requirements and changes were codified in the Submarine Safety Requirements Manual (NAVSEA 0924–062–0010). This manual continues to be the set of formal base requirements for our program today. Over the years, it has been successfully applied to many classes of nuclear submarines and has been implemented for the construction of our newest VIRGINIA Class submarine.

The SUBSAFE Program has been very successful. Between 1915 and 1963, sixteen submarines were lost due to non-combat causes, an average of one every three years. Since the inception of the SUBSAFE Program in 1963, only one submarine has been lost. *USS SCORPION* (SSN 589) was lost in May 1968 with 99 officers and men aboard. She was not a SUBSAFE certified submarine and the evidence indicates that she was lost for reasons that would not have been mitigated by the SUBSAFE Program. We have never lost a SUBSAFE certified submarine.

However, SUBSAFE has not been without problems. We must constantly remind ourselves that it only takes a moment to fail. In 1984 NAVSEA directed that a thorough evaluation be conducted of the entire SUBSAFE Program to ensure that the mandatory discipline and attention to detail had been maintained. In September 1985 the Submarine Safety and Quality Assurance Office was established as an independent organization within the NAVSEA Undersea Warfare Directorate (NAVSEA 07) in a move to strengthen the review of and compliance with SUBSAFE requirements. Audits conducted by the Submarine Safety and Quality Assurance Office pointed out discrepancies within the SUBSAFE boundaries. Additionally, a number of incidents and breakdowns occurred in SUBSAFE components that raised concerns with the quality of SUBSAFE work. In response to these trends, the Chief Engineer of the Navy chartered a senior review group with experience in submarine research, design, fabrication, construction, testing and maintenance to assess the SUBSAFE program's implementation. In conjunction with functional audits performed by the Submarine Safety and Quality Assurance Office, the senior review

group conducted an in depth review of the SUBSAFE Program at submarine facilities. The loss of the *CHALLENGER* in January 1986 added impetus to this effort. The results showed clearly that there was an unacceptable level of complacency fostered by past success; standards were beginning to be seen as goals vice hard requirements; and there was a generally lax attitude toward aspects of submarine configuration.

The lessons learned from those reviews include:

- Disciplined compliance with standards and requirements is mandatory.
- An engineering review system must be capable of highlighting and thoroughly resolving technical problems and issues.
- Well-structured and managed safety and quality programs are required to ensure all elements of system safety, quality and readiness are adequate to support operation.
- Safety and quality organizations must have sufficient authority and organizational freedom without external pressure.

The Navy continues to evaluate its SUBSAFE Program to adapt to the ever-changing construction and maintenance environments as well as new and evolving technologies being used in our submarines. Since its creation in 1974 the SUBSAFE Manual has undergone several changes. For example, the SUBSAFE boundary has been redefined based on improvements in submarine recovery capability and establishment of a disciplined material identification and control process. An example of changing technology is the utilization of fly-by-wire ship control technology on SEAWOLF and VIRGINIA class submarines. Paramount in this adaptation process is the premise that the requirements, which keep the SUBSAFE Program successful, will not be compromised. It is a daily and difficult task; but our program and the personnel who function within it are committed to it.

PURPOSE AND FOCUS

The purpose of the SUBSAFE Program is to provide maximum reasonable assurance of watertight integrity and recovery capability. It is important to recognize that the SUBSAFE Program does not spread or dilute its focus beyond this purpose. Mission assurance is not a concern of the SUBSAFE Program, it is simply a side benefit of the program. Other safety programs and organizations regulate such things as fire safety, weapons systems safety, and nuclear reactor systems safety.

Maximum reasonable assurance is achieved by certifying that each submarine meets submarine safety requirements upon delivery to the Navy and by maintaining that certification throughout the life of the submarine.

We apply SUBSAFE requirements to what we call the SUBSAFE Certification Boundary—those structures, systems, and components critical to the watertight integrity and recovery capability of the submarine. The SUBSAFE boundary is defined in the SUBSAFE Manual and depicted diagrammatically in what we call SUBSAFE Certification Boundary Books.

SUBSAFE CULTURE

Safety is central to the culture of our entire Navy submarine community, including designers, builders, maintainers, and operators. The SUBSAFE Program infuses the submarine Navy with safety requirements uniformity, clarity, focus, and accountability.

The Navy's safety culture is embedded in the military, Civil Service, and contractor community through:

- Clear, concise, non-negotiable requirements,
- Multiple, structured audits that hold personnel at all levels accountable for safety, and
- Annual training with strong, emotional lessons learned from past failures.

Together, these processes serve as powerful motivators that maintain the Navy's safety culture at all levels. In the submarine Navy, many individuals understand safety on a first-hand and personal basis. The Navy has had over one hundred thousand individuals that have been to sea in submarines. In fact, many of the submarine designers and senior managers at both the contractors and NAVSEA routinely are on-board each submarine during its sea trials. In addition, the submarine Navy conducts annual training, revisiting major mishaps and lessons learned, including *THRESHER* and *CHALLENGER.*

NAVSEA uses the *THRESHER* loss as the basis for annual mandatory training. During training, personnel watch a video on the *THRESHER,* listen to a two-minute long audio tape of a submarine's hull collapsing, and are reminded that peo-

ple were dying as this occurred. These vivid reminders, posters, and other observances throughout the submarine community help maintain the safety focus, and it continually renews our safety culture. The Navy has a traditional military discipline and culture. The NAVSEA organization that deals with submarine technology also is oriented to compliance with institutional policy requirements. In the submarine Navy there is a uniformity of training, qualification requirements, education, etc., which reflects a single mission or product line, i.e., building and operating nuclear powered submarines.

SUBSAFE CERTIFICATION PROCESS

SUBSAFE certification is a process, not just a final step. It is a disciplined process that brings structure to our new construction and maintenance programs and leads to formal authorization for unrestricted operations. SUBSAFE certification is applied in four areas:

- Design,
- Material,
- Fabrication, and
- Testing.

Certification in these areas applies both to new construction and to maintenance throughout the life of the submarine.

The heart of the SUBSAFE Program and its certification processes is a combination of Work Discipline, Material Control, and Documentation:

- Work discipline demands knowledge of the requirements and compliance with those requirements, for everyone who performs any kind of work associated with submarines. Individuals have a responsibility to know if SUBSAFE impacts their work.
- Material Control is everything involved in ensuring that correct material is installed correctly, beginning with contracts that purchase material, all the way through receipt inspection, storage, handling, and finally installation in the submarine.
- Documentation important to SUBSAFE certification falls into two categories:
    - *Selected Record Drawings and Data:* Specific design products are created when the submarine is designed. These products consist of documents such as system diagrams, SUBSAFE Mapping Drawings, Ship Systems Manuals, SUBSAFE certification Boundary Books, etc. They must be maintained current throughout the life of the submarine to enable us to maintain SUBSAFE certification.
    - *Objective Quality Evidence (OQE):* Specific work records are created when work is performed and consist of documents such as weld forms, Non-Destructive Testing forms, mechanical assembly records, hydrostatic and operational test forms, technical work documents in which data is recorded, waivers and deviations, etc. These records document the work performed and the worker's signature certifying it was done per the requirements. It is important to understand that SUBSAFE certification is based on objective quality evidence. Without objective quality evidence there is no basis for certification, no matter who did the work or how well it was done. Objective quality evidence provides proof that deliberate steps were taken to comply with requirements.

The basic outline of the SUBSAFE certification process is as follows:

- SUBSAFE requirements are invoked in the design and construction contracts for new submarines, in the work package for submarines undergoing depot maintenance periods, and in the Joint Fleet Maintenance Manual for operating submarines.
- Material procurement and fabrication, overhaul and repair, installation and testing generate objective quality evidence for these efforts. This objective quality evidence is formally and independently reviewed and approved to assure compliance with SUBSAFE requirements. The objective quality evidence is then retained for the life of the submarine.
- Formal statements of compliance are provided by the organizations performing the work and by the government supervising authority responsible for the oversight of these organizations. All organizations performing SUBSAFE work must be evaluated, qualified and authorized in accordance with NAVSEA requirements to perform this work. A Naval Supervising Au-

thority, assigned to each contractor organization, is responsible to monitor and evaluate contractor performance.

- Audits are conducted to examine material, inspect installations and review objective quality evidence for compliance with SUBSAFE requirements.
- For new construction submarines and submarines in major depot maintenance periods, the assigned NAVSEA Program Manager uses a formal checklist to collect specific documentation and information required for NAVSEA Headquarters certification. When all documentation has been collected, reviewed and approved by the Technical Authority and the SUBSAFE Office, the Program Manager formally presents the package to the Certifying Official for review and certification for sea trials. For new construction submarines, the formal presentation of the certification package is made to the Program Executive Officer for Submarines, and for in-service submarines completing a major depot maintenance period the certification package is formally presented to the Deputy Commander for Undersea Warfare. *Approval by the Certifying Official includes verification of full concurrence, as well as discussion and resolution of dissenting opinions or concerns.* After successful sea trials, a second review is performed prior to authorizing unrestricted operations for the submarine.

SUBSAFE CERTIFICATION MAINTENANCE

Once a submarine is certified for unrestricted operation, there are two elements, in addition to audits, that we use to maintain the submarine in a certified condition. They are the Re-Entry Control Process and the Unrestricted Operation/Maintenance Requirement Card (URO/MRC) Program.

Re-entry Control is used to control work within the SUBSAFE Certification Boundary. It is the backbone of certification maintenance and continuity. It provides an identifiable, accountable and auditable record of work performed within the SUBSAFE boundary. The purpose is to provide positive assurance that all SUBSAFE systems and components are restored to a fully certified condition. Re-entry control procedures help us maintain work discipline by identifying the work to be performed and the standards to be met. Re-entry control establishes personal accountability because the personnel authorizing, performing and certifying the work and testing must sign their names on the re-entry control documentation. It is the process we use to collect the OQE that supports certification.

The Unrestricted Operation/Maintenance Requirement Card (URO/MRC) Program facilitates planned periodic inspections and tests of critical equipment, systems, and structure to ensure that they have not degraded to an unacceptable level due to use, age, or environment. The URO/MRC Program provides the technical basis for authorizing continued unrestricted operations of Navy submarines. The responsibility to complete URO/MRC inspections is divided among multiple organizations. Some inspections can only be completed by a shipyard during a maintenance period. Other inspections are the responsibility of an Intermediate Maintenance Activity or Ships Force. NAVSEA manages the program by tracking performance to ensure that periodicity requirements are not violated, inspections are not missed, and results meet invoked technical requirements.

AUDITS

A key element of certification and certification maintenance is the audit program. The audit program was established in 1963. During testimony before Congress Admiral Curtze stated: “To ensure the adequacy of the application of the quality assurance programs in shipyards a system of audits has been established.. . .” This system of audits is still in place today. There are two primary types of audits: Certification Audits and Functional Audits.

In a SUBSAFE CERTIFICATION Audit we look at the Objective Quality Evidence associated with an individual submarine to ensure that the material condition of that submarine is satisfactory for sea trials and unrestricted operations. These audits are performed at the completion of new construction and at the end of major depot maintenance periods. They cover a planned sample of specific aspects of all SUBSAFE work performed, including inspection of a sample of installed equipment. The results and resolution of deficiencies identified during such audits become one element of final NAVSEA approval for sea trials and subsequent unrestricted operations.

In a SUBSAFE FUNCTIONAL Audit we periodically review the policies, procedures, and practices used by each organization, including contractors, that performs SUBSAFE work, to ensure that those policies, procedures and practices comply with SUBSAFE requirements, are healthy, and are capable of producing certifiable hardware or design products. This audit also includes surveillance of actual work in

progress. Organizations audited include public and private shipyards, engineering offices, the Fleet, and NAVSEA headquarters.

In addition to the audits performed by NAVSEA, our shipyards, field organizations and the Fleet are required to conduct internal (or self) audits of their policies, procedures, and practices and of the work they perform.

SUBSAFE ORGANIZATIONAL RELATIONSHIPS

The SUBSAFE Program maintains a formal organizational structure with clear delineation of responsibilities in the SUBSAFE Requirements Manual. Ultimately, the purpose of the SUBSAFE Organization is to support the Fleet. We strongly believe that our sailors must be able to go to sea with full confidence in the safety of their submarine. Only then will they be able to focus fully on their task of operating the submarine and carrying out assigned operations successfully.

There are three key elements in our Headquarters organization: Technical Authority, Program Management and Submarine Safety and Quality Assurance. Each of these elements is organizationally independent and has specifically defined roles in the SUBSAFE Program.

NAVSEA Technical Authority provides technical direction and assistance to Program Managers and the Fleet. In our terms, Technical Authority is the authority, responsibility and accountability to establish, monitor and approve technical products and policy in conformance to higher tier policy and requirements. Technical authorities are warranted (formally given authority) within NAVSEA and our field organizations. Technical warrant holders are subject matter experts. Within the defined technical area warranted, they are responsible for establishing technical standards, entrusted and empowered to make authoritative decisions, and held accountable for the technical decisions made. Where technical products are not in conformance with technical policy, standards and requirements, warrant holders are responsible to identify associated risks and approve non-conformances (waivers or deviations) in a manner that ensures risks are acceptable. NAVSEA is accustomed to evaluating risk; however, non-conformances are treated as an exception vice the norm. Full discussion of technical issues is required before making decisions. Discussions and decisions are coordinated with the Program Management and Submarine Safety and Quality Assurance Offices. However, NAVSEA 05, Ship Design, Integration and Engineering, is the final authority for the technical requirements of the SUBSAFE Program.

- Within the Undersea Warfare Directorate (NAVSEA 07) the Director, Submarine Hull, Mechanical and Electrical Engineering Management Division (NAVSEA 07T) is the warranted technical authority and provides system engineering and support for submarine technical SUBSAFE issues.

Submarine Program Managers manage all aspects of assigned submarine programs in construction, maintenance and modernization, including oversight of cost, schedule, performance and direction of life cycle management. They are responsible and accountable to ensure compliance with the requirements of the SUBSAFE Program and with technical policy and standards established by the technical authority.

The Submarine Safety and Quality Assurance Office (NAVSEA 07Q) manages the SUBSAFE program and audits organizations performing SUBSAFE work to ensure compliance with SUBSAFE requirements. NAVSEA 07Q is the primary point of contact within NAVSEA Headquarters in all matters relating to SUBSAFE Program policy and requirements.

In addition, several groups and committees have been formally constituted to provide oversight of and guidance to the SUBSAFE Program and to provide a forum to evaluate and make changes to the program:

- The SUBSAFE Oversight Committee (SSOC) provides independent command level oversight to ensure objectives of the SUBSAFE Program are met. Members are of Flag rank and represent NAVSEA Directorates (SEA 09, PEO–SUB, SEA 05, SEA 04, SEA 07) and the Navy Inventory Control Point.
- The SUBSAFE Steering Task Group (SSSTG) was established based on results of the *THRESHER* investigation to ensure adequate provision of safety features in current and future submarine construction, conversion, and major depot availability programs. The SSSTG defines the scope of the SUBSAFE Program, reviews program progress and approves or disapproves proposed policy changes. Members include Admirals, Senior Executive Service members and other senior civilian managers with direct SUBSAFE and technical responsibilities, as well as the Submarine Program Managers.

- The SUBSAFE Working Group (SSWG) consists of SUBSAFE Program Directors from Headquarters, shipyards, field organizations, and the Fleet. The Working Group meets formally twice a year to provide a forum to discuss and evaluate SUBSAFE Program progress, implementation and proposals for improvement. SUBSAFE Program Directors are the focal point for SUBSAFE matters and are responsible and accountable for implementation and proper execution of the SUBSAFE Program within their respective organizations. They maintain close liaison with NAVSEA 07Q to present or obtain information relative to SUBSAFE issues.

SUBSAFE CERTIFICATION RELATIONSHIPS

As described earlier in this testimony, each NAVSEA organization is assigned separate responsibility and authority for SUBSAFE Program requirements and compliance. Our technical authority managers are empowered and accountable to make disciplined technical decisions. They are formally given the authority, responsibility and accountability to establish, monitor and approve technical products and policy. The Submarine Program Managers are responsible for executing the SUBSAFE Program for assigned submarines in new construction and major depot availabilities. They have the authority, responsibility and accountability to ensure compliance with technical policy and standards established by cognizant technical authority. NAVSEA 07Q, Submarine Safety and Quality Assurance Office, is responsible and accountable for implementation and management of the SUBSAFE Program and for ensuring compliance with SUBSAFE Program requirements.

The ultimate certification authority is the Program Executive Officer for Submarines (PEO SUB) for new construction and the Deputy Commander for Undersea Warfare (NAVSEA 07) for major depot availabilities. The Program manager, with the concurrence of and in the presence of the technical authority representative (NAVSEA 07T) and the SUBSAFE office (NAVSEA 07Q), presents the certification package with which he attests that the SUBSAFE material condition of the submarine is satisfactory for sea trials or for unrestricted operation. Each of the participants has the authority to stop the certification process until an identified issue is satisfactorily resolved.

NAVSEA PERSONNEL

Our nuclear submarines are among the most complex weapon systems ever built. They require a highly competent and experienced technical workforce to accomplish their design, construction, maintenance and operation. In order for NAVSEA to continue to provide the best technical support to all aspects of our submarine programs, we are challenged to recruit and maintain a technically qualified workforce. In 1998, faced with downsizing and an aging workforce, NAVSEA initiated several actions to ensure we could meet current and future challenges. We refocused on our core competencies, defined new engineering categories and career paths, and obtained approval to infuse our engineering skill sets with young engineers to provide for a systematic transition of our workforce. We hired over 1000 engineers with a net gain of 300. This approach allowed our experienced engineers to train and mentor young engineers and help NAVSEA sustain our core competencies. Despite this limited success, mandated downsizing has continued to challenge us. I remain concerned about our ability, in the near future, to provide adequate technical support to, and quality overview of our submarine construction and maintenance programs.

NASA/NAVY BENCHMARKING EXCHANGE (NNBE)

The NASA/NAVY Benchmarking Exchange effort began activities in August 2002 and is ongoing. The NNBE was undertaken to identify practices and procedures and to share lessons learned in the Navy's submarine and NASA's human space flight programs. The focus is on safety and mission assurance policies, processes, accountability, and control measures. To date, nearly all of this effort has involved the Navy describing our organization, processes and practices to NASA. The NNBE Interim report was completed December 20, 2002.

Phase-2 was initiated in January 2003 with 40 NAVSEA personnel spending a week at the Kennedy Space Center (January 13–17) being briefed on a wide array of topics related to the manufacturing, processing, and launch of the Space Shuttle with emphasis on safety, compliance verification, and safety certification processes. A follow-up trip to Kennedy Space Center and a trip to Johnson Space Center were scheduled for early February 2003. After loss of *Columbia,* the NAVSEA benchmarking of NASA activity was placed on hold until October when 18 NAVSEA software experts were hosted by their NASA counterparts for a week of meetings at Kennedy Space Center and Johnson Space Center. It should also be noted that Naval Reactors hosted 45 senior NASA managers for a "*Challenger* Launch Decision" training seminar at the Washington Naval Yard on May 15.

Three Memoranda of Agreement (MOA) have been developed to formalize NASA/NAVSEA ongoing collaboration. The first, recently signed, establishes a sharing of data related to contractor and supplier quality and performance. The second MOA, in final preparation, establishes the basis for reciprocal participation in functional audits. The third MOA, also in final preparation, will establish reciprocal participation in engineering investigations and analyses.

In conclusion, let me reiterate that since the inception of the SUBSAFE Program in 1963, the Navy has had a disciplined process that provides MAXIMUM reasonable assurance that our submarines are safe from flooding and can recover from a flooding incident. In 1988, at a ceremony commemorating the 25th anniversary of the loss of *THRESHER,* the Navy's ranking submarine officer, Admiral Bruce Demars, said: "The loss of *THRESHER* initiated fundamental changes in the way we do business, changes in design, construction, inspections, safety checks, tests and more. We have not forgotten the lesson learned. It's a much safer submarine force today."

BIOGRAPHY FOR REAR ADMIRAL PAUL E. SULLIVAN

United States Navy, Deputy Commander for Ship Design Integration and Engineering, Naval Sea Systems Command

Rear Admiral Sullivan is a native of Chatham, N.J. He graduated from the U.S. Naval Academy in 1974 with a Bachelor of Science Degree in Mathematics.

Following graduation, Rear Adm. Sullivan served aboard USS Detector (MSO 429) from 1974 to 1977, where he earned his Surface Warfare Qualification.

Rear Adm. Sullivan then attended the Massachusetts Institute of Technology (MIT), where he graduated in 1980 with dual degrees of Master of Science (Naval Architecture and Marine Engineering) and Ocean Engineer. While at MIT, he transferred to the Engineering Duty Officer Community.

Rear Adm. Sullivan's Engineering Duty Officer tours prior to command include Ship Superintendent, Docking Officer, Assistant Repair Officer and Assistant Design Superintendent at Norfolk Naval Shipyard, where he completed his Engineering Duty Officer qualification; Deputy Ship Design Manager for the Seawolf class submarine at Naval Sea Systems Command (NAVSEA), where he completed his submarine qualification program; Associate Professor of Naval Architecture at MIT; Ohio (SSBN 726) Class Project Officer and Los Angeles (SSN 688) Class Project Officer at Supervisor of Shipbuilding, Groton, Conn.; Team Leader for Cost, Producibility, and Cost and Operational Effectiveness Assessment (COEA) studies for the New Attack Submarine at NAVSEA; and the Director for Submarine Programs on the staff of the Assistant Secretary of the Navy (Research, Development and Acquisition).

Rear Adm. Sullivan served as Program Manager for the Seawolf Class Submarine Program (PMS 350) 1995 to 1998. During his tenure, the Seawolf design was completed, and the lead ship of the class was completed, tested at sea, and delivered to the Navy.

In September 1998, Rear Adm. Sullivan relieved as Program Manager for the Virginia Class Submarine Program (PMS 450). During his tour the contract for the Virginia Class Submarine Program was signed, construction was initiated on the first four submarines, and most of the Virginia design was completed. In September 2001 he reported to his current assignment as Deputy Commander for Ship Design Integration and Engineering, Naval Sea Systems Command. Rear Adm. Sullivan's awards include the Legion of Merit (two awards), the Meritorious Service Medal (four awards), the Navy Commendation Medal (two awards) and the Navy Achievement Medal.

Chairman BOEHLERT. Thank you very much, Admiral Sullivan.

Mr. Johnson.

STATEMENT OF MR. RAY F. JOHNSON, VICE PRESIDENT, SPACE LAUNCH OPERATIONS, THE AEROSPACE CORPORATION

Mr. JOHNSON. Thank you. Mr. Chairman, distinguished Committee Members, and staff, I am pleased to have the opportunity to describe the capabilities of The Aerospace Corporation as they relate to organizational and management "best practices" of successful safety and mission assurance programs.

I will discuss the Committee's questions as outlined in the invitation letter, but first, I would like to present an overview of Aerospace and specifically what we do for the Air Force in the area of launch readiness verification.

The Aerospace Corporation is a private, non-profit, California corporation that was created in 1960 at the recommendation of Congress to provide research, development, and advisory services to the U.S. Government in the planning and acquisition of space, launch, and ground systems and their related technologies.

As its primary activity, Aerospace operates a Federally Funded Research and Development Center, or FFRDC, sponsored by the Undersecretary of the Air Force and managed by the Space and Missile Systems Center, or SMC, in El Segundo, California. Our principal tasks are systems planning, systems engineering, integration, flight readiness verification, operations support, and anomaly resolution for DOD, Air Force, and National Security Space systems. Independent launch verification is a core competency of Aerospace, as defined in its charter. As such, Aerospace is directly accountable to SMC for the verification of launch readiness. The verification begins as early as the concept and requirement definition phase of most programs and continues through flight operations. This assessment includes things such as design, qualification, fabrication, acceptance, software, mission analysis, integration, and test.

Prior to any launch, Aerospace provides a letter to SMC documenting the results of the launch verification process, confirming the flight readiness of the launch vehicle. This letter is not just a formality but represents the culmination of a long and rigorous assessment that draws upon the collective expertise of scientists and engineers within the program office and engineering staff.

Now I will address the Committee's specific questions. The first question: "What does it mean for a safety program to be "independent"? How is your organization structured to ensure its independence?"

The Government's requirement for the Aerospace FFRDC mission requires complete objectivity and freedom from conflict of interest; a highly expert staff, full access to all space programs and contractor data sources; special simulation, computational, laboratory, and diagnostic facilities; and continuity of effort that involves detailed familiarity with the sponsor's programs, past experience, and future needs.

Although the Aerospace program offices are co-located with the Air Force programs, they are separate organizations with their own management structure. Technical recommendations are worked up through Aerospace management and are then presented to the Air Force.

The second question was: "Given that more can always be done to improve safety, how can you ensure that your safety program is independent and vigilant, and that it won't prevent the larger organization from carrying out its duties?"

Aerospace recognizes its obligation to identify issues in a timely manner and to keep the Air Force aware of any technical issues that may impact the overall program. The launch verification process is involved with all phases of the program and is not merely

a final assessment that is done just prior to launch. While our technical rigor can identify otherwise unobserved risks, the entire team must work together to allow the larger organization to carry out its duties to achieve flight worthiness certification and a successful mission.

The third question was: "How do you ensure that the existence of Aerospace's mission assurance program and independent launch verification process does not allow the larger organization that it serves to feel that it is absolved of its responsibility for safety?"

Final flight worthiness certification is the responsibility of the SMC Commander. At the final flight readiness review, the Commander receives input from several organizations prior to giving the GO to proceed with launch processing. The Commander receives inputs from the Air Force Mission Director, the launch vehicle program managers, the launch ranges, the SMC Chief Engineer, prime contractors, the spacecraft program managers, The Aerospace Corporation, and also his Independent Readiness Review Team.

Aerospace is directly accountable to SMC for the verification of launch readiness. The ultimate GO/NO-GO launch decision rests with the SMC Commander, not Aerospace. However, the Air Force relies heavily on our readiness assessment in building confidence in the final decision.

And the final question is: "How do you ensure that dissenting opinions are offered without creating a process that can never reach closure?"

The verification process includes all stakeholders at major decision points and milestones. Individuals with dissenting opinion are heard and we make every effort to assure our positions are based on sound engineering practices backed up by factual data. Management encourages the sharing of all points of view and has the responsibility for ultimately deciding on a final recommendation. When a pure technical solution is not possible, the Air Force is provided with a risk assessment that outlines the degree of risk associated with each course of action.

In closing, our success depends largely on the close, intimate relationship we have with our government customers. We are physically integrated and programmatically aligned with our customers. It is this totally integrated approach that allows Aerospace to use its technical and scientific skills in support of the National Security Space Program.

Thank you for the opportunity to describe The Aerospace Corporation, its launch verification program, and contributions to mission success.

I stand ready to provide any further data or discussions that the Committee may require.

Thank you.

[The prepared statement of Mr. Johnson follows:]

PREPARED STATEMENT OF RAY F. JOHNSON

Mr. Chairman, distinguished Committee Members and Staff:

I am pleased to have the opportunity to describe the capabilities of The Aerospace Corporation as they relate to organizational and management "best practices" of successful safety and mission assurance programs. Aerospace is truly a unique organization. Our capabilities, core competencies and practices are the result of 43 years

of operating a Federally Funded Research and Development Center (FFRDC) for the National Security Space program.

I will discuss the committee's questions as outlined in the invitation letter, but first I would like to present an overview of Aerospace and specifically what we do for the Air Force in the area of launch readiness verification.

The nature and value of The Aerospace Corporation

The Aerospace Corporation is a private, nonprofit corporation, headquartered in El Segundo, California. It was created in 1960 at the recommendation of Congress and the Secretary of the Air Force to provide research, development and advisory services to the U.S. government in the planning and acquisition of space, launch and ground systems and their related technologies. The key features of Aerospace are that we provide a stable, objective, expert source of engineering analysis and advice to the government, free from organizational conflict of interest. We are focused on the government's best interests, with no profit motive or predilection for any particular design or technical solution.

As its primary activity, Aerospace operates an FFRDC sponsored by the Under Secretary of the Air Force, and managed by the Space and Missile Systems Center (SMC) in El Segundo, California. Our principal tasks are systems planning, systems engineering, integration, flight readiness verification, operations support and anomaly resolution for the DOD, Air Force, and National Security Space systems. Through our comprehensive knowledge of space systems and our sponsor's needs, our breadth of staff expertise, and our long term, stable relationship with the DOD, we are able to integrate technical lessons learned across all military space programs and develop systems-of-systems architectures that integrate the functions of many separate space and ground systems.

Aerospace does not compete with industry for government contracts, and we do not manufacture products. The government relies on Aerospace for objective development of pre-competitive system specifications, and impartial evaluation of competing concepts and engineering hardware developments, to ensure that government procurements can meet the military user's needs in a cost-and-performance-effective manner.

Aerospace employs about 3,450 people, of whom 2,400 are scientists and engineers with expertise in all aspects of space systems engineering and technology. The professional staff includes a large majority, 74 percent, with advanced degrees, with 29 percent holding Ph.D.s. The average experience of Members of the Technical Staff (MTS) is more than 25 years. We recruit more than two-thirds of our technical staff from experienced industry sources and the rest from new graduates, university staff, other nonprofit organizations, government agencies, and internal degree programs.

Aerospace has maintained a 43-year strategic partnership with the DOD and the National Security Space community, developing a data and experience base that covers virtually every military space program since 1960. We have evolved an unparalleled set of engineering design, analysis and systems simulation tools, along with computational, diagnostic test, and research facilities in critical space-specific disciplines that are used in day-to-day support of government space system programs.

Aerospace is the government's integral engineering arm for National Security Space systems architecture and engineering. As such, Aerospace has broad access to intelligence information, government requirements development, all programs and contractors' proprietary data and processes, and the full scope of government program planning information. We translate the requirements dictated by Congress and the military and national security management into engineering specifications that form the basis for competitive Request for Proposals (RFPs) to industry. We evaluate contractor technical designs and performance, and provide continuing technical insight and progress assessment for the government program manager throughout the engineering development, test and initial operation phases of space systems. In order to do this, Aerospace must have technical experience and breadth at least equal to the industrial firms we evaluate. I am extremely proud of the quality and performance record of our staff, as evidenced by the outstanding success record of the space launches and satellite systems Aerospace has technically supported on behalf of its government sponsors.

The Aerospace technical program office MTS are supported by a matrix of 1,000 engineering and scientific specialists in every discipline relevant to space systems, with extensive laboratory and diagnostic facilities. Typically, an expert in a particular field—propulsion, microelectronics, or infrared sensors, for example—will work on several programs during the course of a year, as each program has a need for a particular skill depending on its program phase. This approach permits Aerospace to develop and maintain state-of-the-art analytical and simulation models and

test facilities that could not be afforded by a single program or contractor, but are efficiently used as needed by all programs.

Aerospace systems engineering currently supports 29 satellite programs, 8 launch vehicle boosters, and 13 ground station elements for the DOD and National Security customers. Our functions can be summarized as follows, covering the entire system acquisition process:

- planning and systems studies—pre-competitive systems definition
- trade-offs and simulations of system requirements to help prioritize user needs
- technical RFPs and technical evaluation of proposals
- early detection of development problems and timely identification of alternative solutions, to preserve schedule, cost and performance
- independent analysis, verification, and validation of data and performance to assure mission success
- launch verification and readiness assessments (boosters, satellites and ground systems)
- launch and on-orbit operations and work-arounds

Aerospace's launch readiness verification process

Independent launch readiness verification is a core competency of Aerospace as defined in our charter as an FFRDC supporting the Air Force. As such, Aerospace is directly accountable to SMC for verification of launch readiness. This responsibility is vested within the Space Launch Operations program offices and executed using our launch readiness verification process.

Prior to any launch, Aerospace provides a letter to SMC documenting the results of the launch verification process, confirming flight readiness of the launch vehicle. This letter is not just a formality, but represents the culmination of a long and rigorous assessment that draws upon the collective expertise of scientists and engineers within the program office and the engineering staff. The launch readiness verification letter provided by the Aerospace Vice President of Space Launch Operations to the Air Force was first introduced in the late 1970s to document our corporate commitment to mission success. This formal launch readiness verification provides assurance that all known technical issues have been assessed and resolved, residual launch risks have been satisfactorily assessed, and establishes confidence in launch mission success. The ultimate GO/NO–GO launch decision and flight worthiness certification rests with SMC, not Aerospace, however, the Air Force relies heavily on our readiness assessment in building confidence in its final decision.

The process used to independently determine launch system flight readiness is a capability that has evolved over 40 years. Aerospace's role in independent launch readiness verification began with the Mercury-Atlas program in 1960, shortly after the corporation was founded. The Project Mercury launch vehicle had suffered two failures and a turnaround in reliability was required before human space flight could be attempted. The risk reduction techniques that Aerospace developed were instrumental in achieving mission success. Since then, we have applied this process to the design, development, and operation of more than 600 launches including all Atlas, Delta, Inertial Upper Stage, and Titan launch vehicle variants resulting in a proven track record of reducing launch risk.

The fundamental features of our launch readiness verification have been the same since first employed. Verification begins as early as the concept and requirements definition phase of most programs and continues through flight operations. Launch verification certification and readiness assessments include design, qualification, fabrication, acceptance, software, mission analysis, integration and test. Thorough launch readiness verification requires a detailed review by Aerospace staff of thousands of components, procedures, and test reports to verify flight readiness. Independent models are developed and maintained by Aerospace domain experts and exercised to validate and verify the contractors' results. Resident Aerospace engineers are involved in all aspects of the launch campaign from manufacture through launch site operations. Launch readiness verification is a closed loop process via post flight analyses that use the independent analytical tools and independently acquired and processed flight telemetry data to provide feedback into the engineering design process, capture lessons learned, monitor trends, and establish a basis for proceeding into the next launch cycle.

To accomplish the entire spectrum of launch readiness verification requires that Aerospace retain a diverse cadre of skilled engineers with expertise in a wide variety of disciplines including systems engineering, mission integration, structures and mechanics, structural dynamics, guidance and control, power and electrical, avi-

onics, telemetry, safety, flight mechanics, environmental testing, computers, software, product assurance, propulsion, fluid mechanics, aerodynamics, thermal, ground systems, facilities and operations. Our major objective is to retain the necessary skills and expertise needed to support planned as well as unexpected events.

The launch readiness verification process was reinvigorated in the late 1990s following a series of launch failures. Among the observations of the Space Launch Broad Area Review were that the root cause was the lack of disciplined system engineering in the design and processing of launch vehicles exacerbated by a premature dismantling of government oversight capability, particularly the engineering support capabilities; that space launch needed to re-establish clear lines of authority and accountability; that space launch is inherently more engineering intensive than other operational systems; and that properly conducted independent review is an essential element of mission success.

Now, I will address the committee's specific questions:

1. What does it mean for a safety program to be "independent?" How is your organization structured to ensure its independence?

The government's requirement for the Aerospace FFRDC mission requires complete objectivity and freedom from conflict of interest; a highly expert staff; full access to all space programs and contractor data sources; special simulation, computational, laboratory and diagnostic facilities; and continuity of effort that involves detailed familiarity with the sponsor's programs, past experience, and future needs. We are focused on the government's best interests, with no profit motive or predilection for any particular design or technical solution.

Although the Aerospace program offices are co-located with the Air Force programs, they are separate organizations with their own management structure. Technical recommendations are worked up through Aerospace management and are then presented to the Air Force. In addition to the launch verification letter, a formal launch readiness briefing is given to the Aerospace president. At this review, our president confirms that our technical analyses are thorough and objective, and our recommendations are based on sound engineering principles. Although the Aerospace launch readiness verification products are produced independently from those of the prime contractor, we also employ another independent review organization that reports to the SMC Commander. This independent review team also briefs our president on its findings to ensure that our process has yielded acceptable risks. This review is conducted just prior to the SMC Commander's Flight Readiness Review (FRR). The Aerospace president is polled during the Commander's FRR for his concurrence to proceed with final launch processing.

2. Given that more can always be done to improve safety, how do you ensure that your safety program is independent and vigilant, but that it won't prevent the larger organization from carrying out its duties?

The key elements here are teamwork, technical rigor, and a goal for 100 percent mission success. Aerospace program offices are co-located with the Air Force programs and Aerospace engineers are in daily contact with their Air Force counterparts. Aerospace recognizes our obligation to identify issues in a timely manner and to keep the Air Force aware of any technical issues that may impact the overall program. The launch readiness verification process is involved with all phases of the program and is not merely a final assessment that is performed just prior to launch. The failures of 1998 and 1999 were in part due to ineffective teamwork. All successes since then can be attributed to a complete team effort among Aerospace, the Air Force, and the contractors. All team members understand and respect the value of the individual responsibilities and contributions. While vigilance and independence can identify otherwise unobserved risks, the entire team must work together to allow the larger organization to carry out its duties to achieve flight worthiness certification and a successful mission.

Just as important as teamwork is the technical rigor employed in the process to reach certification. We employ a well-defined launch readiness verification process with individual responsibilities and accountability. The burden of proof requires a positive demonstration that a system is flight-worthy, rather than proving that an anomalous condition will cause a flight failure. The launch readiness verification process is part of an overarching flight readiness process. Many unforeseen events occur during each launch campaign that must be acted upon. The process rigor that we employ assures that no single event or issue is overlooked or prematurely closed. With 100% focus on mission success, the technical rigor and commitment by each team member enhances the larger organization decision process.

3. *How do you ensure that the existence of Aerospace's mission assurance program and independent launch verification process does not allow the larger organization that it serves to feel that it is absolved of responsibility for safety?*

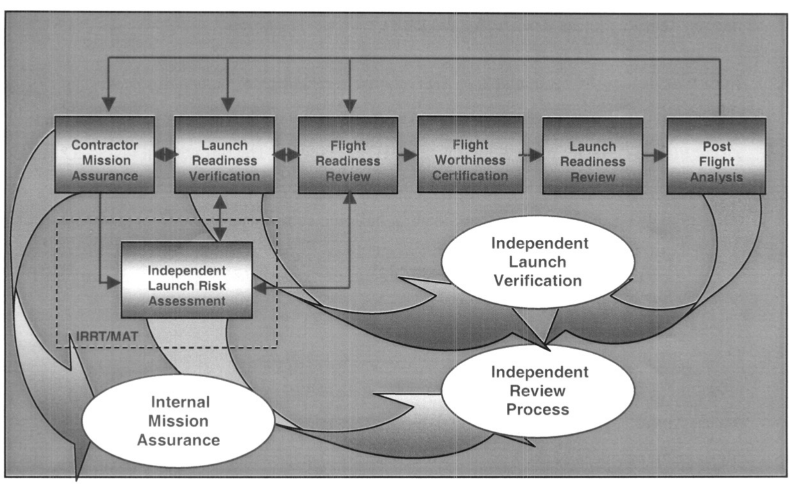
Final flight worthiness *certification* is the responsibility of the SMC Commander. At the final FRR, the Commander receives input from several organizations prior to giving the GO to proceed with launch processing. The Commander receives input from the Air Force Mission Director, launch vehicle program managers, launch ranges, SMC Chief Engineer, prime contractors, spacecraft program managers, Aerospace, and the Independent Readiness Review Team (IRRT).

Aerospace is directly accountable to SMC for the *verification* of launch readiness. Our task is to independently confirm readiness of the launch vehicle, assess mission risks, and assure that all risks are acceptably low to enter into launch. The ultimate GO/NO–GO launch decision rests with the SMC Commander, not Aerospace; however, the Air Force relies heavily on our readiness assessment in building confidence in the final decision.

4. *How do you ensure that dissenting opinions are offered without creating a process that can never reach closure?*

The verification process includes all stakeholders at major decision points and milestones. Dissenting opinions are heard and data is required to resolve engineering issues. Aerospace makes every effort to ensure that our positions are based on sound engineering practices backed up by factual data. Aerospace's engineering staff objectively develops their technical recommendations and supporting analyses that are then coordinated with the Aerospace program offices and management. Management encourages the sharing of all points of view and is responsible for ultimately deciding on a final recommendation. When an issue is well founded in science and engineering, the path forward is usually identifiable, e.g., additional inspections, tests, analyses, etc. For issues that do not have concrete solutions, risks are assessed by senior review teams based on technical data. When a "pure" technical solution is not possible, the Air Force is provided with a risk assessment that outlines the degree of risk associated with each course of action.

As I mentioned previously, the independent launch readiness verification end-to-end system review process culminates in a launch readiness assessment for each mission. A formal flight readiness certification provides assurance that all known technical issues have been assessed and resolved, residual launch risks have been satisfactorily assessed and confidence in launch mission success has been established as acceptable. It is this process, as outlined in the following figure, that ensures acceptable closure of every issue.



Flight Readiness Review Process

I would like to leave you with some concluding summary thoughts:

- Aerospace is focused on the success of its sponsor's mission
- Aerospace is the integral space systems engineering arm of the Air Force and National Security Space program
- The key to Aerospace's value and effectiveness is our process of systems engineering:
  - — stable, objective, expert advice backed by analysis and experiment
  - — a trusted partner with our sponsors and industry
  - — breadth and depth of staff in all space disciplines
  - — access to sensitive planning and proprietary data
  - — continuity across all space programs and technologies
  - — co-location with the government customer

In closing, our success depends largely on the close, intimate relationship we have with our government customers. We are physically integrated and programmatically aligned with our customers. It is this totally integrated approach that allows Aerospace to use its technical and scientific skills in support of the National Security Space program.

Thank you for the opportunity to describe The Aerospace Corporation, its Launch Readiness Verification program, and contribution to mission success.

I stand ready to provide any further data or discussions that the Committee may require.

BIOGRAPHY FOR RAY F. JOHNSON

Ray F. Johnson is Vice President of Space Launch Operations, Space Systems Group. He assumed this position on April 1, 2001.

Johnson is responsible for Aerospace support to all Air Force launch programs including Titan II, Titan IV, Delta II, Atlas II, upper stages and the Evolved Expendable Launch Vehicle (EELV), as well as the Air Force Space Test Program. He has responsibility for the company's launch operations at Cape Canaveral, Florida, and Vandenberg Air Force Base, California, and operations in support of the Space Test Program at Kirtland Air Force Base, New Mexico.

Johnson joined Aerospace in 1987 as a project engineer in the Titan program office. He was promoted to manager of the Liquid Propulsion section in 1988. He was director of the Centaur Directorate within the Titan program office from 1990 to 1993 and was responsible for Aerospace's support in developing the Centaur upper stage for use on the Titan IV launch vehicle.

In November 1993 Johnson was appointed principal director of the Vehicle Performance Subdivision, Engineering and Technology Group, with responsibility for engineering support in the areas of propulsion, flight mechanics, fluid mechanics, and launch vehicle and spacecraft thermal analysis.

Before being named vice president, Johnson was general manager of the Launch Programs Division with responsibility for managing Aerospace's technical support to the Air Force for the Titan, Atlas and Delta launch programs.

Prior to joining Aerospace, Johnson held a number of engineering positions with Martin Marietta Aerospace as part of Titan launch operations at Vandenberg AFB.

Johnson holds a B.S. degree in mechanical engineering from the University of California at Berkeley and an MBA from the University of Chicago. He is a registered professional engineer in the state of California and a senior member of the American Institute of Aeronautics and Astronautics.

The Aerospace Corporation, based in El Segundo, California, is an independent, nonprofit company that provides objective technical analyses and assessments for national security space programs and selected civil and commercial space programs in the national interest.

Chairman BOEHLERT. Thank you very much, Mr. Johnson.

Ms. Grubbe.

STATEMENT BY MS. DEBORAH L. GRUBBE, P.E., CORPORATE DIRECTOR, SAFETY AND HEALTH, DuPONT

Ms. GRUBBE. Good morning, Mr. Chairman, Members of the Committee. I would like to thank you for the opportunity to testify today on the most important issue of safety.

In my work with the DuPont Company, I am a chemical engineer by training. I also have 25 years of experience with DuPont in engineering design, leading multi-million dollar construction projects and running multi-million dollar manufacturing organizations.

Today, I would like to focus my remarks on how we manage safety in the DuPont Company. My overarching message is that good safety practice takes committed leadership, educated personnel, integrated safety systems, and a continuous attention to doing the details of the work.

While DuPont has one of the best safety records in the world, we are far from perfect. Good safety is an elusive dynamic. When we think we are getting good, that is the time we need to start to worry. The key is never to become complacent.

From our experience, we think there are several organizational attributes common to successive—successful safety organizations: number one, safety comes first, and all organizational leadership is actively engaged in safety; number two, standards are high, these standards are well communicated and everyone knows what their role is; number three, our line management is accountable for safety, every person; number four, if the work can not be done safely, it is not done until it can be done safely; number five, safety systems, tools, and process are in place to support high standards and to support implementation and people are trained.

DuPont's safety culture starts at the top of our organization. Our Chief Executive Officer is actively engaged in leading safety. He starts his key meetings with safety. He insists that safety come first on every manager's and employee's list of tasks. He expects to be notified by his direct reports of each employee and contractor fatality or lost-time injury within 24 hours of the event.

Any person can stop any job at any time if there is a perceived danger. Managers and employees are expected to work together to figure out how to do a job safely. If they need more resources, the team obtains them and resolves the problem. Management's role is to support the team and to help find the safest, best solution. Safety is, and must be, a fundamental, line management responsibility all through the organization. Independent bodies can help and assist line managers execute their responsibilities and monitor that execution.

Our corporate safety organization is accountable for being the watchdog on corporate safety policy and for examining how well DuPont executes against its own procedures. This organization, in conjunction with business safety leaders, also develop safety improvements. All improvements, however, are owned and implemented by the line management structure. There are multiple audits to ensure compliance to standards. DuPont never stops looking for weaknesses in its safety systems.

The corporate safety organization reports to a separate executive leader. This person does not have a specific business or manufacturing role and is accountable for integrating safety health and environmental excellence as a core business strategy. His organization works with every DuPont business and functional leader to ensure safe, injury-free operation.

Just as our CEO considers himself the "chief safety officer" for DuPont, each of our managers and supervisors are the chief safety

officers of their respective organizations. They are never relieved of their safety duties. Our collective goal is to have every employee and every contractor that works at our facilities leave everyday just as they arrived. We believe that all injuries and incidents are preventable. Complacency and arrogance are our enemies.

In summary, we believe that any organization can create a safe work environment if it embraces and implements a core set of organizational attributes and values, beginning with the fundamental belief that good safety is achievable and is a core management responsibility.

Thank you for the opportunity to share our experiences with the Committee, and I would be happy to answer any questions.

[The prepared statement of Ms. Grubbe follows:]

PREPARED STATEMENT OF DEBORAH L. GRUBBE

I am a chemical engineer by training and have 25 years of experience with DuPont in engineering design, construction and operations. My current role is Corporate Director—Safety and Health.

Today I would like to focus my remarks on "Safety at DuPont." In summary, good safety practice takes committed leadership, educated personnel, integrated safety systems, and a continuous attention to detail.

DuPont has been in business for over 200 years. We started as a manufacturer of black powder for the U.S. Government in 1802. DuPont first kept injury statistics in 1912, installed an off the job safety process in the 1950's, and worked with the U.S. Government to establish OSHA 1910.119 in the 1980's. Even today, DuPont continues to improve its own safety systems. In 1994, DuPont established a Goal of Zero for injuries and incidents, and in the year 2000, decided to adopt a Goal of Zero for soft tissue injuries like, and not limited to, carpal tunnel syndrome and back injuries.

DuPont always strives to improve its safety performance. In fact, safety is a precarious subject; just when you think you are good, that is the time you should start to worry. The key is to never become complacent. DuPont does have a leadership commitment to put safety first and we are committed to continuous improvement throughout our whole organization.

Safety conscious organizations hold similar organizational attributes:

1. Safety comes first, and all organizational leadership is actively engaged.
2. Standards are high, are well communicated, and everyone knows their role.
3. Line management is accountable for safety.
4. If the work cannot be done safely, it is not done until it can be done safely.
5. Safety systems, tools and processes are in place and training is constant.

DuPont is a large organization, diverse in products, in technologies, and in global locations. However, in spite of this diversity, we have a single safety culture. We have an integrated, disciplined set of beliefs, behaviors, safety systems and procedures. The safety culture is held together by committed and visible leadership. We ensure that our contractors also have similar management processes in place to manage their own safety to high standards.

DuPont safety culture starts at the top of the organization. Our CEO is actively engaged in leading safety. He starts his key meetings with safety, and he insists that safety come first on every employee's list. He expects to be notified by his direct reports, of each employee lost time injury or fatality, employee or contractor, within 24 hours of the event.

Safety at DuPont

Safety management is the unique balance of the carrot and the stick. There must be recognition and reward, as well as serious implications for blatant disregard of safety procedures and standards. If a DuPont employee continuously disregards procedures, he/she endangers his/her life, the lives of his/her colleagues, the shareholders' investment, and the health and welfare of the communities where we do business. We usually prefer that these kinds of people find work somewhere else.

Any person can stop any job at anytime if there is a perceived safety danger. Employees are trained to look out for each other and to ensure that they and their colleagues work safely.

The corporate safety organization is accountable for being the watchdog on corporate policy and for examining how well DuPont executes against its own procedures. This organization, in conjunction with business safety leaders, also develops safety improvements. All improvements are owned and implemented by the line organization. There are multiple audits to ensure compliance to standards. These audits can range from a sales manager observing the driving habits of his/her sales representatives, to an external consultant evaluating how well we conduct our audits. The point is that DuPont never stops looking for weaknesses in its safety systems.

The corporate safety organization reports to a separate leader. This person does not have a specific business or manufacturing role and is accountable for integrating safety, health and environmental excellence as a core business strategy. His organization works with each DuPont leader to ensure there is clear knowledge of the risks present in his/her area, and to ensure safe, injury-free operation.

Just as our CEO considers himself the "chief safety officer" for DuPont, each of our managers and supervisors are the chief safety officers for their respective organizations. They are never relieved of their safety duties. The safety organization in DuPont is sometimes a consultant, sometimes a conscience, and sometimes a leader. Our collective goal is to have every employee and every contractor that works at our facilities leave every day just as they arrived.

In 2002, over 80 percent of our 367 global sites completed the year with zero lost time injuries. While we are proud of the thousands of employees and their achievements; we are not satisfied with this performance. We believe that all injuries and incidents are preventable. Complacency and arrogance are our enemies.

BIOGRAPHY FOR DEBORAH L. GRUBBE

Deborah Grubbe is Corporate Director—Safety and Health for DuPont. She is accountable for leading new initiatives in global safety and occupational health for the $27 billion corporation. Deb was formerly the Operations Director in two of DuPont's global businesses, where she was accountable for manufacturing, engineering, safety, environmental and information systems. Deborah is also a past director of DuPont Engineering's 700 person engineering technology organization. Her 15 different assignments in 24 years range from capital project implementation through manufacturing management and human resources.

Deborah currently serves on the National Institute of Standards and Technology Visiting Committee for Advanced Technology. She also serves the National Academy of Sciences as a member of the oversight committee for the Demilitarization of U.S. Chemical Weapons Stockpile. Deborah sits on the Board of Directors of the Engineering and Construction Committee of the American Institute of Chemical Engineers, and is on the Business Management Advisory Committee of Wilmington College. She is the former co-chair of the Benchmarking and Metrics Committee of the Construction Industry Institute, and currently serves as a member of the Purdue University School of Chemical Engineering New Directions Executive Committee. Deborah was the first woman and youngest elected member on the State of Delaware Registration Board for Professional Engineers (1985–1989). During her tenure on the State Board, she was the Chair of the Law Enforcement and Ethics Committee. She is active with the Society of Women Engineers, and is a former board member of the Women in Engineering Program Advocates Network (WEPAN). Deborah has been featured in the books "Engineering Your Way to Success" and "Journeys of Women in Science and Engineering—No Universal Constants."

She has been active in the Delaware community; as former president and board member of the Chesapeake Bay Girl Scout Council, and currently sits on their Northern President's Advisory Council. Deborah is also a board member of the Delaware Zoological Society. Deborah is a past board member of the YWCA of New Castle County. She has served as a Province President of her sorority, Zeta Tau Alpha, and is a recipient of their Alumnae Certificate of Merit. In 1994, Deborah was named an outstanding Chemical Engineering Alumna by the Purdue University School of Chemical Engineering, and is a recipient of the 1986 Trailblazer Award from the Delaware Alliance of Professional Women. This year, she is a recipient of the Purdue Distinguished Engineering Alumni Award, and has been named "Delaware Engineer of the Year," by the Delaware Engineering Society.

Deborah was born in suburban Chicago and graduated with a Bachelor of Science in Chemical Engineering with Highest Distinction from Purdue University. She received a Winston Churchill Fellowship to attend Cambridge University in England, where she received a Certificate of Post Graduate Study in Chemical Engineering. She is a registered professional engineer in Delaware. She is married to James B. Porter, Jr., and resides in Chadds Ford, Pennsylvania.

DISCUSSION, PANEL I

Chairman BOEHLERT. Thank you very much, Ms. Grubbe, and thank all of you.

ITEA BUDGET INDEPENDENCE

Can you explain—you know, Admiral Gehman, the CAIB Commission, if they have said it once, they have said it a thousand times: safety has to be independent of operational budget considerations. Can you tell me how your organizations, particularly the Admirals', have safety truly independent of the operational segment budgets and schedules? Ms. Grubbe and Mr. Johnson specifically addressed those, and I would like the Admirals to do so.

Admiral BOWMAN. Mr. Chairman, as I listened to Ms. Grubbe, I heard her describing the Naval Reactors organization, also. Many of the elements of her safety program and her operation are identical to what I described as the Naval Reactors organization. I specifically jotted down committed leadership, ingrained safety culture throughout the organization, an integrated safety system, attention to detail, safety owned by line management, a very key point, and that the CEO feels that he is the "chief safety officer." I could just say ditto for the Naval Reactors Program.

And this is a difference in the way I think some are interpreting or perhaps the way the CAIB report is written. Standby for heavy rolls here. I don't believe an organization should have—should rely on an independent organization off to the side to oversee safety. I believe that safety has to be endemic to the organization. It has to be ingrained in every person. I used the word "mainstream." Our line management, likewise, is responsible for safety in our organization. We can not have a separate group that comes in at the end and throws the flag on safety. Safety is a part of the day-to-day design, the day-to-day operation, the day-to-day development of procedures. It is who we are. It is what we are. Every person who is responsible and reports directly to me for components for systems for the entire reactor plant feels the responsibility for safety.

We don't create, therefore, a tension between safety and resources. Safety is a part of the technical line management organization. If one were to arrange a separate safety committee or safety group totally responsible for safety within an organization, I believe that it would be near impossible to avoid this tension between the schedule and the budget, the resources that are necessary. The line management will—would look upon that safety group as Piranhas, not invite them into the campfire at night. They would be pulling in the opposite direction, and I think that the correct way is to ensure that every person within the organization understands that safety is a part of his or her responsibility from the very beginning, from the design and the operation.

Chairman BOEHLERT. You can't emphasize that enough.

Admiral BOWMAN. Yes, sir.

Chairman BOEHLERT. Like you know the old saw where if something is everybody's business, it is nobody's business.

Admiral BOWMAN. Yes, sir.

Chairman BOEHLERT. I mean, it has to be someone. And I think what Admiral Gehman is saying, at least in my interpretation, is

that you need people—everybody has to be devoted to safety, but you need an operation separate from the pressures of scheduling and looking at the calendar. "Can we go on the 14th?" Or, "Do we have to wait until the 15th?" Or, "Do we have enough money to go?" Some—safety has to be totally separate from that, according to my interpretation of the Gehman report and then be able to enter into the equation and say, "Regardless of schedule, regardless of money, here is what we think in terms of safety."

Admiral Sullivan, do you have any thoughts on that?

Rear Admiral SULLIVAN. Yes, sir. I would like to start by echoing Admiral Bowman's remarks about a culture of safety. You can not enforce from above or from beside and catch everything. You will always need to have everyone from the designers to the builders to the operators raised in a culture of safety. That is the best way to get started.

In our submarine safety program, we, in fact, have two checks and balances on the program office, if you will. And I have been on both sides of this. I was the Sea Wolf program manager and the Virginia class program manager, so I have looked at this issue from both sides. The program managers are, in fact, driven by cost and schedule, but the technician authority in NAVSEA is outside of the Program Manager's organization. And the technical authority is, in fact, independent of the Program Manager, and they are funded separately.

The safety—submarine safety organization is also independent of the Program Manager, so, in fact, we have two checks and balances. And both of those organizations can put a stop to a certification process or getting—allowing a ship to get underway, for instance, if there is an issue. And we stop until we get it resolved.

WAIVERS

Chairman BOEHLERT. I am going to interrupt you for a minute, because my—the red light is on and we are trying to stick to the five-minute rule, but I gave you a little flexibility, so I will take a little flexibility here.

But I assume that each of you have a system for waivers, and I would like to know, you know, at NASA they got almost 4,000 waivers, some of them—a third of them are over 10 years old. Do you have a waiver system, Admiral Bowman and Admiral Sullivan? I will ask you to respond to that. How many waivers are in place, and how do you deal with the waivers?

Admiral BOWMAN. There are very few waivers in place in the unforgiving technology that I deal with, the Naval Nuclear Reactors Program. When deviations from specifications occur in manufacturer—in production, they are brought through the system with recommendations and analysis of the overall impact of that deviation on the product, on the system, and on the integrated operation of the plant. Before the decision is made to agree to any deviation, departure from existing written specification and manufacturer production, it is brought to me for final approval. And we, at the table, then, go through that process that I described earlier asking what is the impact, what might be the impact, what is the worst that could happen if we accept this deviation, and what are the minority opinions. Are there people out there in the organiza-

tion who say, "No, don't accept this product; send it back, start over."? We have very, very few of those. It is the—very much the exception and not the rule.

Chairman BOEHLERT. So you would say maybe a handful?

Admiral BOWMAN. Yeah, it would be difficult for me to put a number, sir, but——

Chairman BOEHLERT. Certainly not thousands?

Admiral BOWMAN. Not thousands.

Chairman BOEHLERT. And are you aware of any waivers that might be in existence in your Program that are 10 years old?

Admiral BOWMAN. Deviations from manufacturing tolerances where a manufacturing tolerance might call for something to be between five and 10 mils and it is—in fact, it came in at four mils, we may have those kinds of deviations in existence, but they have been very thoroughly analyzed and determined not to impact the——

Chairman BOEHLERT. Thank you.

Admiral Sullivan, would you care to comment?

Rear Admiral SULLIVAN. We have a similar process outside the propulsion plant where waivers are formally submitted and evaluated. We, too, have few waivers, and I couldn't give you the numbers off the top of my head, but it is a disciplined, rigorous process, and yes, the age of our submarines can be up to—they have about a 30-year service life, but the only waivers that are allowed to stay on a submarine permanently are those of a similar nature to what the Admiral just described.

Chairman BOEHLERT. Ms. Grubbe and Mr. Johnson, I mean you both addressed this directly in your testimony. Do you have anything you would like to add before I go to Mr. Hall?

Mr. JOHNSON. Well, I was just going to add that we do have a process of working waivers. And to give you an idea of the typical number on a Titan 4, which is our—a fairly complex vehicle, we have on the order of about 130 to 150 waivers that we would be working. That has actually been driven down, because there has been a real effort to try and reduce the number of waivers on the vehicle. Probably about four or five years ago, the number was more like around 400 waivers. But we have a process that we review each one of those, provide an engineering assessment and opinion back to the Air Force on those.

Chairman BOEHLERT. Ms. Grubbe.

Ms. GRUBBE. Nothing to add.

Chairman BOEHLERT. All right. Thank you very much.

Mr. Hall.

MANAGING SAFETY

Mr. HALL. Mr. Chairman, thank you for leading in to the—your questions with the word safety. And I think when we think about safety, I guess it is fair to assume that no one at NASA or any of your organizations would deliberately seek to follow unsafe practices. That is outrageous and ridiculous to even think about.

However, back when we were working in the early '80's on the Clean Air Act and worked—I think it took 12 or 13 years to do it, there was a poll that came out that—from one of the Members of the Congress that had sought that poll to try to pass a stronger

Clean Air Act. He had a poll that showed that 82 percent of the people wanted clean air. And I wondered about that other 18 percent what—just what their choice was. But we are 100 percent on safety and seeking it and wanting it and demanding it. And I think that is what you have to do. The problem, though, arises when the pressures to achieve these organizational goals that you men and lady set out, I think, reach the point where the managers and workers find themselves making compromises to follow that schedule or to try to escape the use of a waiver or to have to seek something other than the 100 percent perfection that you have to have when you are going to have safety.

So—well, for example, Admiral Gehman's Investigation Board found that the pressures exerted by NASA's top management to—made an arbitrary date for Space Station Core Complete led to actions being taken that wound up reducing the safety margins of the Shuttle Program, we are told, and I believe that is probably right, because I don't hear anybody that negates that. So I guess I would like to ask each of you, how do you prevent this kind of a thing from happening in your organizations? How have—you been successful in your thrust there or you wouldn't be here. The Chairman selected you to come and give us the best testimony that is obtainable anywhere in the country, and you are here, so apparently you have found a way to prevent that from happening in your organizations. How do you ensure that safety margins can be protected in the thrust that we are on right now? I guess I ask any of you, and if that type of situation does arise, how would you deal with it?

Admiral Bowman.

Admiral BOWMAN. Yes, sir, Mr. Hall——

Mr. HALL. Skip? They call you "Skip," Admiral Bowman?

Admiral BOWMAN. Yes, sir, they do.

Mr. HALL. Do just the normal, ordinary, J.G. like I was 60 years ago, call—come up and said, "Hey, Skip." Would that be okay?

Admiral BOWMAN. No, sir. Maybe I should have said once.

Your question strikes at the very heart of what we are talking about today. And again, I would just have to fall back on the answer that within the Naval Reactors organization, my line management, who are all direct reports to me, we probably have one of the flattest organizations in this country, and certainly within the United States Government, in that all of my direct reports are the first line reports. There is nobody between me and the 21 direct reports at headquarters. They all feel responsible for safety from the beginning. So we don't allow this competition, this competition between schedule, costs, and safety to exist, because we built it into the system from the design, from the redundancy, from the system oversight, the component oversight as it is being developed.

And so we don't allow that to be a topic of conversation that we are supposed to go on sea trials on Monday the 15th of March and if we don't make that, it is going to be a black eye and now we have this safety issue that has reared its ugly head. And the answer is very simple: fix it. Fix it. We build redundancy and safety into our systems for the Commanding Officer of these ships to exercise at sea in battle or in untoward situations. And it is not within my purview. I don't even consider it to be a question that I can remove that redundancy and that safety from him by making a deci-

sion here in Washington, DC that makes the ship less safe before it goes to sea.

I might add, by the way, that I ride all of the initial sea trials on all of these ships and take the ships through all of their evolutions the—for the very first time. So my staff is there with me, and we are there watching the results of the fruits of our labor. So it just doesn't come up. We don't allow safety to be in competition with schedule and budget.

SUBSAFE

Mr. HALL. Admiral Sullivan, your experience on your SUBSAFE thrust, give us the benefit of that.

Rear Admiral SULLIVAN. Yes, sir. First off, as far as waivers coming up and getting pushed aside by the Program Manager, the Program Manager does not have unilateral authority to grant a waiver. He must get technical disposition and that—and he must take a technically acceptable path to disposition of that way. And we do not waive fundamental SUBSAFE requirements, period. And like the Admiral said, when we have an initial sea trial, the toughest certification is the ship going to sea for the first time and the Program Manager also rides.

Mr. HALL. My time is up. Briefly, Mr. Johnson or Ms.—I called you Ms. Grubbe. Is it Ms. Grubbe?

Ms. GRUBBE. Yes, sir, Grubbe.

Mr. HALL. Ms. Grubbe.

Ms. GRUBBE. I would just like to add, very similarly to the other gentlemen, that safety comes first and that anyone at any time can stop anything. And safety does come before budget. I find it interesting that in the collective, when over the years as many people have dealt with safety, we find that we rarely have money up front to do it right, but we always have lots of money at the end to fix it once something goes wrong.

Mr. HALL. Mr. Johnson.

CREW ESCAPE

Mr. JOHNSON. Just very briefly, well, first of all, our whole purpose is a mission assurance or safety organization. We are separate from the Air Force in that respect. We also do have a separate management chain so we are held accountable up—beyond the people that report directly to the Air Force program managers that verify that—and maintain that our mission success focus is something that we never deviate from and never give in to the pressures of schedule and cost.

Mr. HALL. I have one more quick answer—question to ask. I won't require anything but a yes or a no. Do you know of any way that the parents of a person that is going to be launched in one of our Shuttles can feel completely confident without having an escape, modular escape vehicle?

Admiral BOWMAN. Sir, for my purposes, that is outside my realm of expertise. It certainly sounds——

Mr. HALL. You are going to skip that, huh?

Admiral BOWMAN. It sounds like something that should be evaluated. Absolutely.

Mr. HALL. Admiral.

Rear Admiral SULLIVAN. I don't have anything to add to that, sir.

Mr. HALL. You are consistent. Go ahead, Mr. Johnson.

Rear Admiral SULLIVAN. It is—again, it is outside our——

Mr. HALL. Yeah.

Rear Admiral SULLIVAN. Outside our purview.

Mr. HALL. But it is not above your pay scale, is it?

Mr. Johnson, your answer is probably no and Ms. Grubbe, yours is probably no. We have got to have an escape if we are going to feel completely safe, right?

Mr. JOHNSON. That is correct.

Mr. HALL. That is three to two. So we are pretty—no, thank you for your answers. We have to have our fun up here.

Chairman BOEHLERT. Thank you very much, Mr. Hall.

Mr. Burgess.

HANDLING ANOMOLIES

Mr. BURGESS. Well, Mr. Chairman, I want to thank you for convening this panel today. It has truly been very instructive and necessary for us as we make our evaluations about the *Columbia* Accident Investigation Board report.

The—when Admiral Gehman was here before, he talked about applying the template to NASA where there is a strict adherence to safety and how to treat an anomaly and continue flying. And yet I read in the Washington Post yesterday an editorial about apparently accepting an anomaly with the on-board environment on the Space Station and continuing—continue with the mission to put some additional astronauts up there. So the question comes up are we really serious about that and, Admiral Bowman, would that be an acceptable anomaly in your experience to continue flying?

Admiral BOWMAN. I fly underwater. If we were faced with a similar situation of—or if we were faced with a situation of not being able to monitor the ship's environment, that would be cause for not allowing the ship to sail.

Mr. BURGESS. All right. Thank you.

On the—just following on the same line that the Chairman and Mr. Hall have been pursuing, do you have—could you share with us, any of you, a real-world example of how your organization has handled a particular safety problem, particularly one where an ongoing mission of your larger organization had to be interfered with?

Rear Admiral SULLIVAN. I can give you an example of it some years ago when we were trying to deliver the Sea Wolf, which was a program with not a great reputation on the Hill. We were about six months from final sea—first sea trials and a working level engineer at one of our ship builders, who was working on the design, came up with a concern about the Titanium alloy we were using on the doors to the torpedo tubes, which are the largest holes on the ship. He pulled the thread on that and eventually got it pulled up through the organization, which is also flat. Our organization is not as flat as Naval Reactors, but it is flat enough that minority opinions, such as this, are voiced. And it came into—this was in about 1994. It came to full attention of the program management and technical and safety staff. And we had to come to a grinding halt, do a bunch of testing, and replace that material on those

doors, and it delayed the ship delivery a year, and it cost in excess of $50 million by the time we were done. And it is because we couldn't compromise the safety.

Mr. BURGESS. Admiral Bowman, would you have an example from the Nuclear Reactor Program?

Admiral BOWMAN. Questions of safety are—with the nuclear reactors for the Naval Reactors Program are not quite so dramatic that we get to the end of the trail and suddenly have to make a decision like Admiral Sullivan just described, because we begin with safety in mind all of the way at the beginning of the design and the manufacturing process, and we will watch it and monitor it. And then as we test the completed components in a non—not—in a critical reactor environment, we then may run across things that require safety adjudications. So we fix it then. And then we go on to the next level of test program. And so as the test program moves along, safety items that might exist, that very seldom do exist, but that might exist, come to the floor earlier than as Admiral Sullivan just described. So I am racking my brain right now to think of an equivalent, and I can't think of one.

Mr. BURGESS. Well, the yellow light is on, so just for a minute more, if we had a similar situation or we had the situation with, of course, the *Columbia* with the foam, but in your experience in your organization, it would have never gotten to the—to that point. That anomaly would have been selected out much earlier in the process? In the design and manufacturing?

Admiral BOWMAN. Well, it is difficult to say conclusively, but I would dare say yes.

Mr. BURGESS. Thank you very much. I will yield back the balance of my time, Mr. Chairman.

Chairman BOEHLERT. Thank you very much, Mr. Burgess.

Ms. Johnson.

Ms. JOHNSON. Thank you, Mr. Chairman, and thank you for having this hearing. I have an opening statement of which I will put into the record.

Chairman BOEHLERT. Without objection, so ordered.

All Members will have their opening statements in the record immediately following the opening statements from the distinguished Ranking Member.

SAFETY ACCOUNTABILITY

Ms. JOHNSON. Thank you. There was comment, I think by the Admiral, that indicated he thought the CEO should be the one in charge without a separate organization. I don't think NASA had a separate organization, but the CEO, the person who occupies that, did not get the information. How do you think that could be improved?

Admiral BOWMAN. Again, an excellent question. I think what Ms. Grubbe said and I agree with was that her CEO at DuPont felt himself to be the "chief safety officer." And certainly, within my organization, I feel myself to be the "chief safety officer." Let me—if I could for just one minute, I do have, at Naval Reactors, a safety group, but that safety group is not responsible on a day-to-day basis for ensuring the safe design and manufacture and production and operation of the components. That is the line management's re-

sponsibility to me directly. So the way we do it, as the design is moving along, as the system is operating, as we go day to day with these 103 reactors that I spoke of earlier that I am responsible for, I hear in real time these difficulties that we are encountering. And the line management know that they are responsible for safety as well as for delivering the product.

So again, the tension isn't there. What my safety group does for me is integrate the overall efforts of the organization. They keep the safety codes. They are responsible for the computer codes that evaluate the overall safety of the reactor plant. And they do the liaison with the Nuclear Regulatory Commission for Naval Reactors for me. But they are not—and I found this out dramatically early on in my tour when I asked a safety question about a reactor coolant pump. And I asked it of the safety group head, and you would have thought the world was coming to an end. Within minutes, the owner of that reactor coolant pump, the line manager who designs and oversees the reactor coolant pump, was in pounding my desk saying, "What are you doing asking the safety group head about my stuff?" And I think it is that sense of ownership and that sense of responsibility that leads to this mainstreaming that I am talking about. And that is the way that we do it at Naval Reactors. I would hear about it within minutes of something happening.

Ms. JOHNSON. So though you have persons that have expertise generally in particular areas, the communication loop always includes you for the final decisions?

Admiral BOWMAN. Yes, ma'am, it does.

Ms. JOHNSON. Thank you.

Mr. Johnson, is that the way you function at DuPont?

Mr. JOHNSON. I am The Aerospace Corporation. And actually, in our case, in the case of the Air Force launch organization, the CEO, the appropriate person in that same position would actually be Lieutenant General Arnold, who is the Space and Missile System Commander. The program managers that manage the overall launch programs actually work for him. And the information always flows up to General Arnold, to answer your question. The program managers do a very good job of doing that, and the final flight readiness review is actually chaired by General Arnold, and he is the one that gives the final GO decision based on the inputs of all of the various agencies, The Aerospace Corporation being one of them, but also his Program Manager and several others.

Ms. JOHNSON. Ms. Grubbe.

Ms. GRUBBE. Congresswoman, at the DuPont company, everyone has the same accountability for safety: from the CEO to the operator in the control room on the night shift. And it is our intent to make sure that everyone would behave and make the decisions with regard to safety in the same way.

Ms. JOHNSON. Thank you very much.

Does anyone on the panel have a comment of what—your opinion of what might have broken down at NASA?

Admiral BOWMAN. As I said, Congresswoman, in my opening testimony, I just don't consider myself to be expert enough in this area and have not studied it well enough to offer an opinion.

Ms. JOHNSON. Thank you very much.

Is that a signal that my time is up?

Chairman BOEHLERT. Yeah, that is it. All right.

Ms. JOHNSON. Thank you.

DECISION-MAKING IN THE NAVAL REACTORS PROGRAM

Chairman BOEHLERT. Thank you very much.

Admiral Bowman, let me ask you, does Naval Reactors make a decision on when and whether to launch, or does it go topside at Navy?

Admiral BOWMAN. I—this gets difficult. I have—both wear a hat within the Navy as the Director of Naval Reactors as a four-star admiral, and I am also an Assistant Secretary of Energy overseeing the safe operation, the oversight regulation of the safe operation of Naval Reactors. In that job, I have the final say over whether a Reactor is safe to operate. And so there is no over my head in that regard. And certainly, I report to the Secretary of Energy in that regard, in that role, and to the Secretary of the Navy in the Navy role.

Chairman BOEHLERT. Well, then you would say you are comparable to the Administrator of NASA in that regard? In other words, you have the final say on when and whether to launch?

Admiral BOWMAN. When and whether to allow operation of the Reactor plant. The ship's operation is a different matter. The Reactor plant is the propulsion system that drives the ship through the water. Without it, the ship couldn't get underway. So I do have a veto vote that the ship couldn't leave if I felt there was something unsafe that—to preclude safe operation of the Reactor plant. But the contrary is not true. There may be things that are beyond my purview having to do with the submarine safety areas that Admiral Sullivan oversees that I could say my Reactor plant is perfectly ready to go and safe to operate, but the ship doesn't leave because now it does leave my hands and go——

Chairman BOEHLERT. Yeah, I——

Admiral BOWMAN [continuing]. Above my head. Yes, sir.

Chairman BOEHLERT. Thank you very much for that clarification.

Mr. Gutknecht.

CULTURE AND ATTITUDE

Mr. GUTKNECHT. Thank you, Mr. Chairman.

And I apologize to our distinguished guests for the attendance here, because you need to understand, we understand—sometimes people in the audience don't understand we have a number of other Committee meetings going on at the same time. And I want to thank the Chairman for calling this hearing, and I want to thank you for coming. I have never had the courage to go out on one of these weekend submarine missions, which some of my colleagues have done. I have spent a few hours on one, and I must tell you, I am in admiration of those brave Americans who go out sometimes for months at a time and serve this country. So please pass that along to the people that work under you.

Let me—the issue here is about safety, and I want to come back to something, because I believe the single most important word in the English vocabulary is the word "attitude." And I think if anything happened that I have learned so far and in what we have

learned in terms of the Shuttle catastrophe is that the attitudes at NASA had become a little bit sloppy. And you went through—the Navy went through a similar process, I think, after *Thresher.* I guess the question that this committee really wants to get at, after the *Thresher,* and I think this is for Admiral Sullivan, did you start, essentially, with a blank sheet of paper and start over, or did you tend to—did you try to modify the current structure that was there? And I think that is a fundamental question we need to get at relative to NASA. And perhaps you could offer some observations on that.

Rear Admiral SULLIVAN. I would say in response to the *Thresher* disaster, we basically went all the way to our roost and rebuilt the culture. The first thing we did was restrict the operating depth of all operational submarines at the time. Then they revised the operating procedures. And of course, this was many years ago. Submarine operating procedures were revised. We went through a review of the design of our submarines and made a number of changes that fundamentally changed the way we had our safety systems in our submarines design including redundancy, putting in a special emergency blow system, and having redundant backups for closing major openings into the ship if the primary system failed. We also worked hard on our diving plane hydraulic systems so that we would have increased reliability. We started the whole audit process. We formalized—we changed the way we joined our pipes. Before *Thresher,* many of the pipes that carried water inside the ship where they were—water coming in from the sea were used silver-braise joints. We went from silver-braise joints to welded joints, which are much more reliable and can be inspected more easily and with more reliability. So we really changed the whole operating design and manufacturing culture of the program. It took a long time.

Mr. GUTKNECHT. But Admiral, did you change your organizational structure?

Rear Admiral SULLIVAN. I wasn't there then. I was a kid. I—there was no SUBSAFE group, that is for sure.

SUBSAFE'S USE OF THE CHALLENGER CASE STUDY

Mr. GUTKNECHT. The—and let us come back to that SUBSAFE group. Now apparently, I am told, that you used the *Challenger* accident as part of your training program. Can you tell us a little bit about that?

Rear Admiral SULLIVAN. Yeah, I am glad you mentioned that, because I wanted to talk about how you combat complacency in a culture of safety. Basically, whenever any complex system fails, including *Challenger* and including all of the Soviet Navy's submarine losses, we try to fold that into our training. We hold annual training on everyone who works on the submarine program who works at SUBSAFE. And the training consists of two parts. One is a kind of review of all of the procedures and instructions, and the second part is a formal—I will call it a lecture, but we actually watch a video every year that describes the whole lead up and loss of *Thresher,* including a tape of the audio of the submarine pressure hold breaking up. And that is pretty sobering to go through every single year. And you know, I have heard it an untold number

of times, and it sends a chill through my bones every time I listen to that tape.

So I—again, what you have to do is combat complacency.

Mr. GUTKNECHT. But do you use the *Challenger* incident?

Admiral BOWMAN. My organization uses the *Challenger* incident as formal training. In fact, just yesterday I was at one of my two Department of Energy laboratories speaking to a fairly large crowd outside. And I spoke then about the *Columbia* Accident Investigation Board and its report and how we needed to do exactly the same thing with *Columbia* as we have done with *Challenger*. One of the first books I read upon taking this job over seven years ago was Diane Vaughn's book on the loss of the *Challenger*. And we have ingrained that training as a formal routine part of our training at Naval Reactors.

We use a phrase called "constructive dissatisfaction" to attack what Admiral Sullivan was just speaking of, complacency within an already pretty safe organization. I argue that if we are not constructively dissatisfied with where we are and with the status quo, we are going to find ourselves on the right road but standing still, and we are going to get caught some day. So the *Challenger* training is a big part of that training.

Mr. GUTKNECHT. Well, thank you very much.

NASA/NAVY BENCHMARKING

Chairman BOEHLERT. Thank you.

Just let me ask you, how long, Admiral Bowman, have you been in your current job? Eight years?

Admiral BOWMAN. Seven years and 28 days.

Chairman BOEHLERT. And Admiral Sullivan, how long?

Rear Admiral SULLIVAN. I have been at my job just over two years.

Chairman BOEHLERT. I am just wondering, between—in the last half a dozen years or so prior to the tragic February 1 accident of *Columbia*, was there interaction between NASA and your organization?

Admiral BOWMAN. Yes, sir, there was. Early on in Mr. O'Keefe's tenure, he socialized with me the possibility of benchmarking the Naval Reactor's culture against what he had found at NASA. He subsequently formally asked the Secretary of the Navy for permission to do that discussion, benchmarking with my organization as well as with Paul Sullivan's organization. The Secretary of the Navy, of course, obliged happily, and we began that benchmarking operation months before the tragedy.

Chairman BOEHLERT. Of course, Mr. O'Keefe has prior experience with the Navy, so he was fully aware of your outstanding program.

Admiral BOWMAN. Yes, sir.

Chairman BOEHLERT. But I am comforted to hear that. But you guys, in the Navy, learn from the *Challenger*, and that is a case study.

Admiral BOWMAN. Sure.

Chairman BOEHLERT. I sometimes wonder if NASA learned from *Challenger*. They ought to study it as seriously as you did.

Mr. Miller.

Mr. MATHESON. How about Mr. Matheson? Thanks.

Chairman BOEHLERT. This paper, who says what? Mr. Matheson. Yes, sir.

CAIB RECOMMENDATIONS

Mr. MATHESON. Thanks. Thanks, Mr. Chairman.

I want to thank you for your testimony on safety practices in your own organizations. What I would like each of you to tell us is what specific benchmarks you think ought to be established to evaluate whether or not NASA is complying with the Board's organizational recommendations. And as part of your response, I would like you to give a thought about how long you think it should take for an organization like NASA to implement those recommendations.

Admiral BOWMAN. Boy, that is a good question. And I have given very little honest thought to it, because it is not my responsibility. If I could possibly back off for just a couple of days and provide that answer for the record, I will devote——

Mr. MATHESON. That would be great.

Admiral BOWMAN [continuing]. A lot of resources to thinking about it. But I just haven't given it adequate thought to answer.

Rear Admiral SULLIVAN. I would just add that probably the best forum for that is to just continue the benchmarking effort that is going on between NASA and NAVSEA right now.

Mr. MATHESON. If you—go ahead.

Mr. JOHNSON. I was just going to add that I think probably the best benchmarks are the items that are contained in the recommendations in the report itself. And it could take a considerable amount of time to set up an organization like that. Of course, we don't know exactly what it is that NASA is going to set up, but that could be easily a year-long effort to set up an organization like that.

Mr. MATHESON. Sure. Sure.

Ms. GRUBBE. Congressman, I can not speak to the benchmark question, but in DuPont's work with other clients with regards to changing their own safety culture, it takes—if management is committed, if the management of the company is committed, it takes roughly 18 to 24 months to see substantive changes.

COMMUNICATING RISK

Mr. MATHESON. You know, one issue that we deal with that, you know, as Congressmen, we are dealing with the public all of the time in town meetings or what not. And I am wondering how do your organizations address public—the public's concern about risk? How do you try to communicate how you are dealing with risk? How do you try to build up that knowledge within the public that your organization is addressing risk issues? And how do you think that would apply to NASA? You can just go in the same order. Yeah.

Admiral BOWMAN. I am going to reverse the seating next time.

Within Naval Reactors, there has been a consorted effort over the past five or six years to do more of what you are suggesting. We

are little bit hamstrung, because a great deal of what I deal with is classified——

Mr. MATHESON. Right.

Admiral BOWMAN [continuing]. And it is protected by the Atomic Energy Act of 1954. And so I have to be cautious. I honestly believe that I am dealing with the country's crown jewels, or at least some portion of them, in our nuclear submarines and nuclear aircraft carriers. I know, without question, that my organization is targeted by other nations for this technology, so we have been careful.

Mr. MATHESON. Sure.

Admiral BOWMAN. That said, we recognize that—the point of your question, that it was very important to begin developing more trust with the public than perhaps we had before. So we asked ourselves what could be discussed, and we began a program that I—from my Tennessee background, if Mr. Gordon were here, called hobnobbing. And I began encouraging my field representatives who oversee the operations in the various ports where our submarines and aircraft carriers are located or where my Department of Energy laboratories are to begin discussions with the public officials, the State officials, and the Federal officials who co-regulate some of our activities to bring them in and, at the table over a cup of coffee in a non-extreme kind of situation, tell them who we are and what we are trying to do and begin working even on security clearances for some of these people so that we can bring them into the inner sanctum and let them know better what we are doing to protect the environment and to protect the—their public.

We are highly reliant on these State and local officials to take care of their people in our ports. So we felt very strongly that it was important to do that. So I would say that we have had now a number of these discussions with State officials in all of the states that we operate in as well as beginning now to do what I call table-top drills, training scenarios that would walk us through the what-ifs and the highly improbable event of an incident that would require the town or the state to mobilize, what would be required. And so we have been doing a great deal of that, most recently with the State of Washington and their Adjutant General attended that with us.

Mr. MATHESON. Thank you, sir.

Chairman BOEHLERT. Thank you very much. The gentleman's time has expired. Did anyone else need to respond to that? Thank you very much.

Mr. Smith.

TURNOVER IN THE SAFETY WORKFORCE

Mr. SMITH. Mr. Chairman, thank you.

Congress tries to fulfill its role of policy, and sometimes that policy sort of interferes with some of the goals of the Administration or the Navy. I served in the Nixon Administration for about five years. And pretty much what we were told when we came on the Hill is, you know, try not to rile any of the Congressmen. Be nice. Be polite. I am a little concerned with NASA that has been somewhat immune from political control even—from Congress, but also even from the White House over the last several years. And so I am trying to—I guess my question relates partially to the balance

of that policy coming from Congress to—at what point it—is it disruptive to the mission as determined by the Administration versus as the responsibility for policy oversight by Congress. But I don't know how you answer a question that is sort of vague like that, except let me specifically talk about the difference between the Navy and the NASA in terms of complacency, how complacency starts to evolve from employees that have been doing the same thing for too long a period. And as I understand it, Admiral Bowman, the Navy has an 8-year transition in some of the more technical aspects. And NASA has now told us that they are looking at a rotation of two to three years, so a new broom will sweep clean, if you will, but—so it is a balance of the energy and attentiveness of new people coming on the job versus the potential of complacency. What is the right length of time for rotation and transition?

Admiral BOWMAN. Well, that is another very good question and I think one that should be addressed by this committee in dealing with this NASA situation. You are right. My particular position is, by law, eight years. On the day Admiral Rickover retired, President Reagan wrote an Executive Order that made that so, and that Executive Order has subsequently been written into law twice now, making my tenure eight years.

I think longevity in this kind of oversight position that I find myself in is extremely important to the safe operation of an organization that deals with an unforgiving technology, such as mine or NASA's. So I heartily endorse both that concept of extending the tenures of key technical people at NASA as well as what Secretary Rumsfeld is trying to do across the Navy for this—or across the military for——

Mr. SMITH. You are recommending that it be done by law?

Admiral BOWMAN. Well, that is certainly one way to ensure that it gets done. It is a way that it could happen. It is the way it has happened with my position.

Mr. SMITH. Well, according—but you know, part of my concern with past hearings on the *Columbia* disaster, and I appreciate the question that was asked earlier that the Navy looks at *Columbia* in terms of what possible mistakes have they made in reaction—in relation to what we are doing and how do we make sure that we don't make the same mistakes. NASA, I think, is going to start being more conscious of a larger environment.

NANOTECHNOLOGY

I have been concerned about the mission. I am Chairman of the Subcommittee on Research. A lot of the justification for our NASA effort is research. We have been told that the main reason that humans are in space is to—studying—scientifically, at least, is studying the physiological implications on humans in space flight. I just returned from Cal Tech and JPL and looking at some of the California science efforts. And I guess I come back with the conclusion that our new nanotechnology is going to replace a lot of the manned space flight. How about nanotechnology in communication to replace more personnel in the Navy, especially with submarines?

Admiral BOWMAN. We are headed in that direction, without question, the entire Navy, not just submarines. Looking at automation. Nanotechnology may very well have a place in that in the sensor

world, being able to better determine what is going on inside systems and inside components with nanotechnology. But reducing the manpower on board our warships is a stated goal as the Chief of Naval Operations and the Secretary of the Navy even—one which I endorse.

NASA/NAVY BENCHMARK

Mr. SMITH. Is there—just one last quick question.

On your investigation and how it might apply to you and your responsibilities in terms of reviewing what happened with *Columbia*, do you communicate any of that analysis or evaluation to NASA?

Admiral BOWMAN. I am sure we will. I say that because of the earlier questions that indicated that Mr. O'Keefe was keen on benchmarking his organization against the Navy's organization. So I would have no doubt that he would be interested in our views on lessons learned from *Columbia*. I would add that we have already conducted training for NASA on *Challenger*, giving them our version of the lessons that we learned from the *Challenger* disaster——

Mr. SMITH. Okay.

Admiral BOWMAN [continuing]. And I think they found that very helpful.

Chairman BOEHLERT. Thank you very much. The gentleman's time has expired.

Mr. SMITH. Thank you.

Chairman BOEHLERT. Ms. Jackson Lee.

MANNED VS. UNMANNED SPACE FLIGHT

Ms. JACKSON LEE. Thank you very much. And to the panelists, I think I associate my remarks with my colleague who has indicated that there are a number of hearings going on that may have delayed us in hearing your complete testimony, but I want to thank the Chairman and Ranking Member for a very, very vital hearing.

And I would like to probe extensively, within my time frame, on this question of safety. Realizing that Admiral Gehman and the *Columbia* Investigation Board set a standard of which we should try to achieve, I have noted over the years, starting halfway, probably, into my term, maybe even earlier, on this committee, which has been a sizable amount of time, that safety is the number one responsibility and requirement. And I would then add to say that we are at a crisis point as it relates to safety issues in moving NASA forward. Admiral Bowman, just a quick question. My colleague led you down the path of technology and manpower and possibly substituting technology for manpower. I assume reducing manpower does not, in your mind, equate to eliminating manpower as it relates to submarines.

Admiral BOWMAN. In some instances——

Ms. JACKSON LEE. In totality, I am trying to say.

Admiral BOWMAN. No, not in totality. Absolutely not.

Ms. JACKSON LEE. Okay. Then let me—I just wanted to make sure that I got that on the record that technology will never, in totality, replace the necessity of manpower, humanpower,

womanpower, if you will, if they have reached that point of staffing on the submarines. And I don't believe that it will reach the point of eliminating the importance and vitality of human space flight. You are not here today suggesting that we should eliminate the human Space Shuttle?

Admiral BOWMAN. The——

Chairman BOEHLERT. All right. Excuse me. That is not at all the purpose of the hearing. The purpose of the hearing is to learn from them how do we make——

Ms. JACKSON LEE. I understand.

Chairman BOEHLERT [continuing]. Human flight safer.

Ms. JACKSON LEE. I appreciate. Let me allow the gentleman—would you answer my question, please, Admiral? Thank you.

Admiral BOWMAN. It was certainly not my intent to indicate any opinion on the elimination of manned space flight in my answer.

Ms. JACKSON LEE. Right. So you are not here suggesting that that should be eliminated or make a comment on that?

Admiral BOWMAN. That is correct.

SAFETY ORGANIZATION

Ms. JACKSON LEE. Okay. The CAIB has indicated that we should divide the structure of NASA between operations and safety. Is that along the lines of what you have done with respect to the operations that you are involved in the Navy?

Admiral BOWMAN. We really have done almost the opposite.

Ms. JACKSON LEE. All right.

Admiral BOWMAN. We have integrated operations and safety. We have combined operations and safety from the beginning. As I have said earlier, the mainstreaming aspect of safety with the line functions does that for you and makes everybody responsible for and cognizant of safety.

Ms. JACKSON LEE. And how have you found—has that been a structure that you have had for a number of years? Has it been a structure that you have implemented in response to actions that have occurred? Or has this been the Navy's general basis of operations?

Admiral BOWMAN. Admiral Rickover set up his office at Oak Ridge in 1948, and this has been a part of Naval Reactors since 1948.

Ms. JACKSON LEE. And in that integration of safety issues, how do you encourage the personnel in the Navy to be open on their concerns about safety questions, for example, and I think it was asked before but I would like to hear it again, if there is an air quality problem or a safety problem in a submarine that was about to disembark or about to leave shore, if you will, with my—with the technology to be refined better? But in any event, what would be the response to that individual or individuals?

Admiral BOWMAN. I think they would be rewarded and applauded. They certainly would be in my organization in our——

Ms. JACKSON LEE. And how do they go up the chain of command?

Admiral BOWMAN. Within my organization, it is quite easy. They have direct access to me, number one, through knocking on my door and coming in the office, calling me on the telephone, e-mail. They have direct access to their section heads. The direct reports

that I referred to earlier, the 21 direct reports, know that we are going to be talking at the table in my office about are there minority opinions, are there dissenting opinions on the consensus view here. And so they go out and look for it.

Ms. JACKSON LEE. So the atmosphere can be created, you are saying?

Admiral BOWMAN. I believe it can, yes, ma'am.

Ms. JACKSON LEE. Ms. Grubbe, would you—thank you very much, Admiral.

Would you help me with the safety question in the private sector? We find that there are concerns of retaliation and enforcement questions on how do you enforce the atmosphere or penalize those who don't do it. What do you do in the private sector with DuPont?

Ms. GRUBBE. We do something very similar to the Navy, Congresswoman. We reward and highlight people who bring forward not only safety events that have occurred where no one else was around, but potential events and make sure that they get broad communication across the organization and to every plant site around the world that has a similar kind of apparatus, if it involves a piece of equipment.

Ms. JACKSON LEE. We thank you very much for your reasoning on this. This will be instructive to us as to what we need to do, and I thank you for your testimony.

Chairman BOEHLERT. Thank you very much.

Mr. Rohrabacher.

Mr. ROHRABACHER. Well, I am just going to say that I missed the testimony, and I am sorry, and I apologize. We have got our Governor-elect Arnold in town, and I was introducing him to various people, and that is part of my job, and I am sorry. But I will be reading your testimony. And I appreciate the fact that you have shared your expertise with us. We have to put NASA's house in order, and all of us on the outside and the inside have to work together. And I appreciate your contribution and appreciate Sherry Boehlert's leadership. Thank you very much.

Chairman BOEHLERT. Thank you very much.

And now I would like to thank the panel for participating, for serving as resources. We value highly your testimony in its entirety. And all of your complete testimony will be part of the permanent record and any added material you care to submit. And stay tuned, we may be back by phone or by written communication to ask for some amplification of certain segments of your testimony, but we really appreciate what you have done. Thank you very much.

Panel II

Our next panel will be a panel of one, the very distinguished Chairman of the *Columbia* Accident Investigation Board, Admiral Harold Gehman. Admiral Gehman has had a busy day. He has been over to the JV's this morning. He is coming to the Varsity right now in the Science Committee of the House of Representatives. As we all know, Admiral Gehman has been just outstanding in his service to the Nation in a very important capacity as Chairman of the *Columbia* Accident Investigation Board. Let me add, he

has also been outstanding in many other respects, including his availability to all of the Members of this committee and to the staff of the Committee. We are working hand-in-glove with the Admiral to ensure that we have the best possible response to a very tragic situation.

And with that, now that the name tag is properly in place and the Admiral is prepared, Admiral Gehman, welcome back.

Admiral GEHMAN. Thank you very much.

Chairman BOEHLERT. The Floor is yours, sir.

STATEMENT OF ADMIRAL HAROLD W. GEHMAN, JR. (RET.), CHAIRMAN, COLUMBIA ACCIDENT INVESTIGATION BOARD

Admiral GEHMAN. Thank you very much, Mr. Chairman.

I will just make a very, very short opening statement here, and we will get right to the questions.

The panel that you just had, I didn't get to listen to all of it, but I got to listen to part of it, a very illustrious panel. I consulted their organizations in the course of our investigation, and I congratulate this committee for getting them here and letting them talk about safety and reliability.

Let me just say that the *Columbia* Accident Investigation Board was careful to—we tried to be careful to separate safety from reliability. By safety, we referred to—we refer to things like untoward incidents in the workplace or hazardous conditions or hazardous materials or the failure to inspect or to catch something. Reliability refers to completing the mission, that is launching safely and returning safely with all of the humans intact. And we—they are related to each other, but at the same time, the Board came to the conclusion that the organization and structure needed to accomplish these two goals with slightly—a slightly different approach. And therefore, we made these three organizational and structural organizations the—that you are conducting this hearing on. And it is the opinion of the Board that there is almost nothing in our report, which is more important than getting this right. We really feel that if the Board—if the *Columbia* Accident Investigation Board is going to be viewed as having been successful, then making these changes in NASA will be the measure of whether or not we were successful.

In the area of reliability, we feel very strongly that separating technical and engineering authority from the operation of the Shuttle is the key to increasing the reliability and accomplishing the mission. Right now, we are successfully launching and recovering the crew and the Shuttle 55 out of 56 times. And that is not what I would call a high reliability record. There are a lot of activities in the United States which are very dangerous, very hazardous, and which have success rates far in excess of 55 out of 56. Certainly you had Naval Reactors here and the Navy Submarine Program as well as DuPont and The Aerospace Corporation. And they—their goal is zero failures to accomplish their mission. And they don't consider 55 out of 56 to be anything to brag about. So the separation of the technical and engineering authority, we believe, is one of the keys—is the key to doing that.

The second area is safety. As NASA is organized right now, the Headquarters safety organization is independent and that is not

the issue. The problem that we have is that the Headquarters safety organization, Code Q, Mr. Brian O'Connor, with—in whom we have the highest confidence, does not have any line authority. He is the policy setter. And it is—it isn't that the Headquarters safety organization is not independent. That is not the issue. The problem that we have is that the Headquarters organization doesn't have any authority. And then the program and center safety organizations are subordinate and are dependent upon the programs and centers, that is the very organizations that they are supposed to check up on, are the ones that are funding their activities. And we have—it is the—so it is the program and the center safety programs that we think are not independent, not the Headquarters safety program.

The last thing I would say before I respond to your questions is that the Board carefully studied these institutions whose representatives you just had here, plus some others, and we also availed ourselves of more than a dozen academic experts in the area of high-reliability operations and safety. And we will admit to you—we will admit, unashamedly, that we selectively picked and chose the attributes and characteristics of these organizations, which we thought added to reliability. We did not copy lock, stock, and barrel either the Naval Reactor's model, the SUBSAFE model, the Aerospace model, or any other model. We picked the attributes that we liked the best and put our formula in the report. And the longer that this report stands out here, the more scrutiny it has gotten, the stronger we feel that we got it right.

So with that, Mr. Chairman, I will be glad to answer your questions.

[The prepared statement of Admiral Gehman follows:]

PREPARED STATEMENT OF HAROLD W. GEHMAN, JR.

Good afternoon Mr. Chairman, Representative Hall, distinguished Members of the Committee, ladies and gentlemen.

It is a pleasure to appear today before the House Science Committee. I thank you for inviting me and for the opportunity to provide answers to questions you may have as you endeavor to implement the recommendations of our report on the investigation into the tragic loss of the Space Shuttle *Columbia* and her courageous crew of seven.

My intent during my testimony today is to provide the Committee with information on any of the topics explored by the *Columbia* Accident Investigation Board in the final report. I am prepared to explore any area in which you or the Committee are interested; however, I would like to remind you that now that the Board has disbanded, my ability to speak on its behalf is limited. I cannot comment on the progress of the NASA's return to flight, as I have not been involved in an oversight role. I do wish to make myself available to explain any facets of the report that may be unclear or require further clarification.

That said, I would like to turn my attention to the questions provided in the charter of this hearing.

The first question asks what it means for a safety program to be independent. I believe we must clarify which independent safety program we are discussing. The Board found that the NASA Headquarters Code Q safety organization is completely independent. Our finding referred to the Center and Program Safety Offices. We do not think the current process by which the Center and Program Managers "buy" as much safety as they can afford or think they need is the best organizational construct. When safety competes against all other budget items such as schedule, maintenance, upgrades, pay raises, etc., safety sometimes is compromised. In regards to the NASA Headquarters Safety Office addressed in Recommendation 7–2.5, the Board's concern was not lack of independence, but rather the lack of a direct line of authority over a safety organization whose jurisdiction runs all the way down to the shop floor.

The second question concerns how to balance the organization of safety programs to give them sufficient robustness and efficiency, but without preventing the larger organization from carrying out its duties. Safety organizations should not have veto authority over operations, but they do need the expertise and depth to understand the systems completely, the ability to initiate and resource at least a minimal study or inquiry on their own without having to ask project management, sufficient personnel to be present at critical tests and inspections, proper test equipment, and sufficient resources to fund studies that help reveal what trends mean and what the safety organization should be looking for.

Thirdly, the Committee asks how to ensure that the existence of an independent safety program does not allow the larger organization to absolve itself of responsibility for safety. The safety organization should not supplant the operations organization for operational decisions. The safety organization just needs to be robust enough and independent enough to study an issue, understand multiple sides and all the implications of the actions contemplated, come to a conclusion that is supported by analysis, testing and research, and then have a chance at the proper forum to voice their independent position.

The Committee's last question concerns ensuring that dissenting opinions are heard, but avoiding the possible impasse resulting from a safety review process that can never reach closure. The Board has reached the conclusion that holding and voicing dissenting opinions is not the problem. The problem comes when dissenting opinions are not supported by data. What the CAM recommended are procedures that ensure that reliability and safety matters can be thoroughly examined by knowledgeable people with sufficient resources. This process does not guarantee that errors won't be made, but the current NASA process doesn't even give the system the chance to catch mistakes.

Thank you, Mr. Chairman. This concludes my prepared remarks and I look forward to your questions.

DISCUSSION, PANEL II

ISS SAFETY AND CAIB RECOMMENDATIONS

Chairman BOEHLERT. Thank you very much, Admiral.

You are aware, and so are all of us, of the issue of the Space Station and what has transpired over the last several days and the extensive coverage given to the issue and how it was handled. If your recommendations had been in place, how do you think it would have been handled differently?

Admiral GEHMAN. Mr. Chairman, I do not—I only know about this case of the air and water quality on the International Space Station from what I read about in the newspapers. I do not have any knowledge of the actual details of who said what to whom and who went to what meeting and all of that sort of thing. But I can speak to that incident in the context of the mosaic presented by our report. First of all, if there are technical standards for air, water quality, and if there are monitoring instruments up there, the operation of those instruments and the enforcement of the air—of the environmental quality and the safety of the people in the International Space Station would be the purview of this engineering technical authority. And the Program Manager could not waive those standards. He could not say, "No, I am going to go anyway." That is—that would not be one of his functions. He would have to go to the independent technical and engineering authority and say, "Well, I have looked at this, and I have decided that we should go ahead and replace this crew. Even though these instruments aren't working the way they are supposed to, we have no reason to believe that there is"—anyway, he would make his argument, and it would be up to this independent technical authority to determine whether or not it wanted to waive its own standards. If it chose

not to waive—and to get to your question specifically, the—whoever these people were who decided not to sign off on the flight readiness review, they would be operating in an environment in which they would be on the inside. That is, they are in an engineering environment in which actions like this are rewarded and are encouraged rather than having to prove that something was wrong.

Sooner or later, it would have to come to some person, probably the head of human space flight, or something like that, who would have to decide which way to go. That is okay. And if they decided to go ahead anyway, that would be fine. But I—but the big difference would—the big difference in my view would be that, as I understand it, and Mr. O'Keefe sat beside me a couple of hours ago and he just explained his action here, as I understand it, these dissenting opinions were encouraged. They were fired up on. They were taken seriously, but they were all taken seriously because of the good graces and the cooperative attitude of management. And I—the history of the Space Shuttle Program and NASA, going all of the way back to Apollo, indicates that over a period of 18 to 24 months, those good graces and that cooperative attitude will atrophy and the old pressures of schedule and manifest and cost will come back again.

Chairman BOEHLERT. And it never got topside until the last 72 hours. I mean——

Admiral GEHMAN. Yeah, that—I don't know any of those details, but the big difference would be, in my opinion, that these dissenting opinions, these concerns would be voiced in an organization that was not concerned about schedule, not concerned about cost, and it would be in a friendly environment. These people would not be, kind of, on the outside trying to get their way in.

SAFETY PROGRAM INDEPENDENCE

Chairman BOEHLERT. Well, what—how do you consider the Naval Reactors Program independent, because we just heard from Admiral Bowman that there is nothing separate? I mean, safety is everybody's business. It is the culture that he is talking about. Everybody is totally immersed in safety first and foremost. And it—there doesn't seem to be the independence that you outlined, the Board outlined in its recommendations.

Admiral GEHMAN. Mr. Chairman, I listened to part of that, and I think that there was a misunderstanding, even though Admiral Bowman tried to clear it up at the end. Admiral Bowman and his organization are responsible for the Reactor and all of the requirements of the Reactor, all waivers to the Reactor, and all operations of the Reactor, but they are not responsible for the ship, the submarine. There is a—the Fleet is responsible for the operations of the submarine. And that is our model with—the Program Manager who is responsible for the operations of the manifest of the Shuttle and then a technical authority that is responsible for the technical specs and requirements of the Shuttle.

Admiral Bowman and his organization can say, "That Reactor is not ready to operate," in which case the Fleet Commander can't operate the submarine. But Admiral Bowman doesn't operate the submarine. Once he says it is okay, then someone else decides

where the submarine goes, how fast it goes, what date it goes out——

Chairman BOEHLERT. Got it.

Admiral GEHMAN [continuing]. When it comes back, and so when he says that the whole line organization is responsible for safety, he was referring to his line organization. He was referring to his pump guys and his——

Chairman BOEHLERT. Thank you for that clarification.

Admiral GEHMAN. Yeah.

Chairman BOEHLERT. Ms. Jackson Lee.

ISS SAFETY

Ms. JACKSON LEE. Thank you very much, Mr. Chairman, again. And thank you, Admiral Gehman——

Admiral GEHMAN. Thank you.

Ms. JACKSON LEE [continuing]. For having the willingness to be at bat more than once today.

Since you have been here, your work is continuing, and our challenges are continuing. And so rather than dance around the question, let me go right to it. You had been answering the question, but might I say that I think we were engaged earlier, as you well know, when I say we, myself in questioning, raised the issue of safety on the International Space Station. And I think now we are in dialogue through written communications to try and expand on that understanding. I believe that maybe it was good for us to have this happen sooner rather than later with respect to the issue of exposing the difficulties.

There are two prongs that I would like to probe with you. One, we found, again, if you will, and you have not done an extensive review of the Space Station but use your background and experience with your view of *Columbia* 7, the tragedy that occurred there. The first prong, of course, is that there were, in this instance, two very vocal scientists who offered their opinion and, I believe, refused to sanction and/or prove the sending of two additional astronauts to that—to the Station. What should have happened or what went wrong, maybe that would be the better approach, that they were either overrun, superseded? Was that healthy? Was there—and you may be gleaning this from newspaper articles, but what went wrong from that perspective?

The other perspective is that is it viable and important at this time now to do a comprehensive safety assessment on the Space Station? Again, I remain committed to the value of humans in space and certainly human Space Shuttle. But for it to be a successful experiment, which I think Space Station is, there is no doubt that we are still experimenting with what goes on in space, but do we need that right now without one moment's rest or stop in beginning to assess the safety issues on that—on Space Station?

Admiral GEHMAN. Thank you very much, Ms. Jackson Lee.

From what I understand of the incident over—the incident having to do with the approval of the Crew 8 mission, I believe that it is—if you take the matrix or the test of the *Columbia* Accident Investigation Board report and apply it to that event, I believe it looks like this. In the first case, there is some good news. For example, one of the issues that we raised in our report was it—that

it seemed to us that over the years that engineers and scientists had to prove that a situation was unsafe before the Shuttle Program would take any action, whereas in the original days, you had to prove it was safe in order to go forward. And the fact that the test now seems to be "prove to me that it is unsafe" is the wrong question. For example, in the case of the engineers in the case of *Columbia* who wanted photography, wanted imagery on-orbit, they were told to prove that there was a problem before management would go ahead and get the photography. That is a case of "prove that it is unsafe before I take any action," whereas the original Apollo philosophy was "you have to prove to me that it is safe or I am not going to go forward."

Okay. In the case of the atmosphere and the water situation, the human conditions on board the International Space Station, it does appear to me that NASA management asked the question, "All right, you are going to have to prove to me that it is safe." That is the correct question. So it looks to me like they have learned that—in this case, they have learned their lesson. The—so that is the good news in this particular incident.

The bad news, or the thing that I am concerned about is the same issue that I brought up with the Chairman and that is it appears to me that it took the intervention, the act of intervention of management to resolve this issue. In other words, the system didn't take care of this problem by itself. And a year from now, or 18 months from now, when cost and schedule pressures have resumed, I am—I don't think we want to rely upon the intervention of management to snatch victory from the jaws of defeat. I think we want to institutionalize a process by which these issues can be raised and sorted out without having top-level management intervene.

Chairman BOEHLERT. Thank you very much, Admiral.

Admiral GEHMAN. And the second question, to get to your second question, we kind of have a cookbook here. We only looked at the Shuttle Program. I think that probably the International Space Station Program ought to be looked at, also, but I—but not with the same urgency, of course.

Ms. JACKSON LEE. Thank you.

Chairman BOEHLERT. Thank you, Ms. Jackson Lee.

Mr. Rohrabacher.

LEADERSHIP CONFIDENCE

Mr. ROHRABACHER. Yes. Admiral Gehman, Mr. O'Keefe, Director O'Keefe, has my full faith in his decision-making. Does he have your faith?

Admiral GEHMAN. Yes, sir. I—of course, I only have seven months of experience, I mean, since the 1st of February, and——

Mr. ROHRABACHER. Almost as much as his.

Admiral GEHMAN. Well, that is right. He is—that is right. He has only been there slightly longer than that, but in the course of this investigation, he has provided us all support, everything we have asked for. He has taken all of the right moves, as far as I can tell, so yes. The answer is yes.

ISS SAFETY

Mr. ROHRABACHER. Okay. And the episode with this Space Station decision that had to be made, you were satisfied with the way that that has been handled?

Admiral GEHMAN. Well, once again, I don't know the details of who said what to whom. And—but it did appear to me, just based on the limited knowledge that I have, including listening to Mr. O'Keefe explain it to the CST this morning, that it took the active intervention of management to bring this issue up to the proper level. And I would rather see a system at work in which it didn't take the active intervention of senior managers to bring something up. It ought to come up automatically.

Mr. ROHRABACHER. And since the issuance of your report, your— you would give NASA an "A"? A "B"? A "C"? An "F"?

Admiral GEHMAN. Since the issuance of our report, myself and other members of the Board have continued to dialogue not only with NASA on a regular basis, we have been asked—invited by Mr. O'Keefe to come over and address his senior management, and we continue to hammer, and hammer, and hammer. But also, we have an active dialogue going on with the Stafford Covey Return To Flight Task Group so that they understand exactly what we mean by every recommendation. So we are—you know, it is early yet, and we are still in the thinking stage. We are not in the doing stage yet, but so far, so good.

VISION

Mr. ROHRABACHER. One of the things that I believe we discussed when you were sitting there before was the lack of—the importance of a lack of vision statement and the importance of lack of an overall goal that people would—could unify behind and those type of goals actually energize the system. I haven't seen anything come forward from the Administration yet along those terms. Is it necessary? Do you still believe that it is necessary to have this vision and unified concept for NASA to work at its peak efficiency?

Admiral GEHMAN. Yes, sir. The Board was quite straightforward and firm in that finding. It wasn't a recommendation, but we felt very strongly that the lack of an agreed, and by agreed I mean both ends of Pennsylvania Avenue as well as the American public, an agreed vision for what we want to do in space gets in the way of a lot of very practical day-to-day things. For example, NASA doesn't know, nor do you know, how much money to put into infrastructure upgrades if you don't know where you are going. You don't know how much money and how high a priority Shuttle upgrades and Shuttle safety upgrades should be accorded, because you don't know how long the Shuttle is going to last. You don't know—NASA doesn't know how to justify to you major investments. And indeed, in the case of the orbital space plane, it is not clear exactly what this thing is supposed to do because we don't have an agreed vision as to what we want to do.

So it gets in the way of doing business on a daily basis, not only at the national level, not only at your level, but at the practical level down at the Cape and down at Marshall, because they——

Mr. ROHRABACHER. And in terms of the individual level, you might correct me if you disagree, but I imagine you do, that individuals who are working within a system are energized and there is a new dynamic created in their—in the way they work and the care that they take if they feel that they are part of something that is much larger than just the task of the day. And without a consensus or a concept that is going to—a unifying concept, we are not going to be able to do our job, are we?

Admiral GEHMAN. Well, I think that the—all of the workers and all of the scientists and engineers as well as the contractors that we came in contact with, which was quite extensive, as you know, because we did interviews on the shop floor, we did interviews in the back room, they all appeared to be motivated and serious and quite dedicated to their project. I think I mentioned to you and to other Members of this committee that early in our investigation, we were—when we were doing view graph 101, when we were getting hundreds and hundreds of view graphs, we actually had presenters choke up and break down while they were briefing us, just to show how dedicated they are.

But I believe that—in the—that where your question really hits the mark, Mr. Rohrabacher, is in the area of problem solving. Now if we don't really have a good vision, a good, exciting vision that people can buy into, we don't really address some of the problems as aggressively and imaginatively as they would if they knew where they were going.

Mr. ROHRABACHER. Thank you very much. Thank you, Mr. Chairman.

Chairman BOEHLERT. Thank you very much.

Mr. Wu.

EXPEDITION 8 LAUNCH DECISION-MAKING PROCESS

Mr. WU. Thank you, Mr. Chairman.

Thank you for coming again, Admiral.

I want to ask one question and then one follow-up. And the question is—somewhat follows up on the Chairman's earlier question and Ms. Jackson Lee's earlier question about the decision to launch this latest group of people to the International Space Station and the fact that there were, in fact, in essence, two dissenting opinions. And there was a process. There was dissent. There was discussion, and apparently that occurred over a period of time, and now there are two astronauts in the International Space Station. We have a solar flare that occurred yesterday and it is arriving just about at this time: an unpredicted event, difficult to predict, and in this case, unpredicted. Was this decision-making process and the fact that now these two astronauts have to get into the thickest part of the International Space Station and move water around, perhaps, and so on, is that a sign that the process is working because two people were able to consent, or is that a sign that this process is not improving because we are where we are with the solar flare and two astronauts up and the radiation monitors not working?

Admiral GEHMAN. Right. Well, my understanding—and certainly we studied this in the case of the Shuttle Program in great detail. My understanding is that in the process of certifying a vehicle for

a launch or a mission to go, I would consider dissent to be a good thing. There are so many variables and so many pieces and so many subsystems that—there are so many risks and so many assumptions that have to be made that if everybody said, "Yes, yes, we are ready to go. No problems. Everything is good to go," I would be suspicious that somebody is hiding something from me, because it is so complex and so dangerous. There is so much energy involved. There are so many systems involved. There has got to be some—out there, there has got to be somebody who is having a little problem with his system or he has some doubts about something. And if that person doesn't speak up, that is what I would be concerned about.

So the fact that there were some environmental scientists, or medical doctors in this particular case, who were concerned about some aspect of it, to me is not a sign of a failure or a sign that anything is going wrong or anything like that. The lack of any dissent would cause my suspicions to go up. And once again, I do not know in detail of how this dissent was handled or who did what to whom and who held what meeting, only what I have heard Mr. O'Keefe testify to this morning and what I have read in the newspapers. And I had already said that it looked to me like it took active management intervention to get that sorted out. And that is not a long-term formula for success.

Mr. WU. Thank you, Admiral.

The follow-up question I have is that, according to what I have heard, Administrator O'Keefe learned of this problem only days before the launch even though the dissents occurred a significant time prior to that. And as a Member of this committee, I don't know if the Chairman had better access to the information, but I learned about the dissents through the newspaper. Is this—the panel we had earlier said, "You know, one of the things about safety is you build it in so that it goes to the top and everyone has responsibility and the loop loops in the person who is ultimately responsible." And the fact that, perhaps Administrator O'Keefe did not know until, maybe, soon before the launch and that members of this oversight committee didn't know until it was published in the newspaper post-launch, is that a sign of a challenge or a problem to be faced?

Admiral GEHMAN. I think we should not comment on that here, because in his testimony this morning before the Senate, Mr. O'Keefe said that that was not true. And we ought to let him sort this out. As I say, I do not know who said what to whom on what day, but in his testimony this morning, Mr. O'Keefe said that that press report of when he was told and how he was told was inaccurate. And so we ought to let him sort that out.

Mr. WU. Thank you, Admiral.

Chairman BOEHLERT. Thank you.

Mr. WU. Thank you, Mr. Chairman.

ITEA AND SAFETY STAFF TURNOVER

Chairman BOEHLERT. A quick one before I go to Mr. Smith for the final question for you. How important do you think it is, Admiral, to have longevity in the staff of the independent technical and safety organizations?

Admiral GEHMAN. Well, I think that longevity is one of the attributes that would aid in the efficiency and effectiveness of that organization. It is also the opinion of the Board, by the way, that this independent technical and engineering authority or whatever it eventually gets called, would also aid in some of NASA's career progression and retaining issues, because right now there are very troublesome career moves of into contractors and out of contractors and back and forth. And I would really like to see a more healthy progression of, you know, into the—into a true engineering organization than back into the program and back into engineering. So we think it is very important.

Chairman BOEHLERT. That is a view we share. It is—we are working with NASA to give them the ability to restructure in how they do things and to treat their workforce a little bit differently because of the proven need.

All right. Mr. Smith, for the final——

ISS REVIEW

Mr. SMITH. Mr. Chairman, I am—very briefly. And Mr. Chairman, I agree with you that Administrator O'Keefe was correct when he decided that the reorganization of NASA should occur before the return to flight, really setting a more ambitious schedule than that called for by the CAIB.

Admiral, let me ask you exactly what you meant when you said there should be a further evaluation of the Space Station. Are you talking about policy, goals, objectives, what it is accomplishing, or are you talking about safety?

Admiral GEHMAN. Any kind of a review whatsoever. I am speaking—that was a private opinion. So I have got no evidence to go on to indicate that there were—there are any problems in International Space Station.

Mr. SMITH. Well, there is hope——

Admiral GEHMAN. But my private opinion is, though, that the kind of look we looked at their management schemes here and how safety is handled probably would be a good idea for the International Space Station to get the same kind of examination.

Mr. SMITH. But even more than that, I would think, last weekend, I am sure you are aware that a report by NASA scientists was, for lack of a better word, leaked that described the human physiological research at the Station as voodoo science. And NASA science, I think, has identified that the physiological research on humans is essentially all of the justification why humans would be in space. And of course, I am an advocate of dramatic reductions at this time of real financial problems with the Federal Government and the debt that we are facing to review all programs. And so I think when we look at the Space Station, we also need to look at what it has accomplished. And I think that we should consider, in some kind of investigation, whether it is—and I suspect maybe you would like to visit with your family some more as far as you taking the responsibility of it, but should we drastically reduce manned space flight and should we maybe abandon the Space Station?

Admiral GEHMAN. I am sorry. I am going to have to defer on that——

Mr. SMITH. I knew you—all right.

Admiral GEHMAN [continuing]. Mr. Smith. We did not look—we did a lot of ancillary research to make sure that the report that we wrote was—is in much context as we possibly could. We put it in budget context, history context, everything else like—but the one context that we did not look at was the argument between how much human space flight is enough. And so I just am not a——

Mr. SMITH. And again, thank you for your great work and service to the country.

Admiral GEHMAN. Thank you.

Mr. SMITH. And Mr. Chairman, I yield back. Thank you.

Chairman BOEHLERT. Thank you very much. And what you said, very eloquently, and you have said it many times, we need a national debate, a good thorough vetting of the issues. And we have got to reach some sort of a consensus that gives us a vision.

Admiral GEHMAN. Yeah.

Chairman BOEHLERT. And we have got to work toward it. Thank you very much, Admiral Gehman.

Admiral GEHMAN. May I make one 30-second last closing statement here——

Chairman BOEHLERT. By all means.

Admiral GEHMAN [continuing]. And that is that the fundamental—the three fundamental organizational recommendations that we made that is there should be an independent technical engineering authority. That is the most important one. That the Headquarters safety organization should have line authority. Now that doesn't mean that the Program can't have a safety organization and the center can't have a safety organization. They certainly can. But for the—for your head of safety to be only a policy-setter doesn't seem to be——

Chairman BOEHLERT. Right.

Admiral GEHMAN [continuing]. Reason for us. And the last one, that the Shuttle Program should have a true integration—a systems integration office, which it does right now. In reflection over time and listening to all of the experts, we are more convinced than ever that those are good, solid recommendations, and we stand by them. And I didn't hear anything from this panel this morning which changed my opinion.

Thank you very much, Mr. Chairman.

Chairman BOEHLERT. Well, thank you. And you have not disappointed us. We have always come to recognize that we get good, solid recommendations from you.

Thank you very much. This hearing is adjourned.

[Whereupon, at 12:19 p.m., the Committee was adjourned.]

Appendix 1:

Answers to Post-Hearing Questions

ANSWERS TO POST-HEARING QUESTIONS

Responses by Admiral F.L. "Skip" Bowman, Director, Naval Nuclear Propulsion Program, U.S. Navy

Questions submitted by Representative Ralph M. Hall

Columbia Accident Investigation Board Recommendations

Q1. How will we know that NASA has implemented the Columbia *Accident Investigation Board (CAIB) recommendations? What measures do you use in your organization to determine that your safety mechanisms are working?*

A1. I do not have firsthand knowledge of the pertinent details of NASA's technology and organization. However, I do note that in many ways they are different from that of the Naval Nuclear Propulsion Program (NNPP). Therefore, I cannot provide useful guidance on how to best determine if the CAIB's recommendations are implemented.

As to how I determine if safety mechanisms are working in my own Program, I have several methods using many inputs. My staff and I are personally informed of or briefed on every significant naval nuclear propulsion plant problem; from this, we determine if additional causes need to be identified or if additional corrective actions (technical or administrative) need to be taken. In addition to performing site inspections, Reactor Safeguards Examinations (RSE), and personal site or ship visits, my staff and I receive reports from my many field representatives, from contractor and other Program organizations, and from commanding officers of nuclear-powered ships. I expect them to find problems—if they don't, my instincts based on a more than 30-year career as a nuclear-trained operator tell me that they probably aren't looking hard enough. Issues identified in those reports are evaluated to see whether corrective actions (again, either technical or administrative) are required. Similarly, I expect dissenting opinions on difficult decisions and if there are no dissenting opinions, my experience tells me that they haven't asked all the right people for input. In addition, I frequently insert my own "dissenting opinions" ("devil's advocate") into the discussion and have those carefully examined. As Admiral Rickover said, "One must create the ability in his staff to generate clear, forceful arguments for opposing viewpoints as well as for their own. Open discussions and disagreements must be encouraged, so that all sides of an issue will be fully explored."

My safety inspection process is extensive. Headquarters personnel at the most senior level personally evaluate performance and compliance in the field. Headquarters staff conducts regular inspections of work, safety, and environmental and radiological controls. Headquarters evaluation teams are made up of the technical-requirements owners (who are responsible to me for all safety aspects of their areas) for the particular areas being assessed. This ensures that the evaluation team has an indepth understanding of not only the requirement, but also its significance, letting the evaluation team identify issues and trends that might not be discerned if auditing were done solely by checklist. Additionally, field office personnel routinely conduct audits and inspections as part of their responsibility to monitor the work of Program laboratories, prototypes, the Fleet, shipyards, and prime contractors. The DOE laboratories, the nuclear-capable shipyards, and the Fleet also must conduct self-audits, assessments, and inspections. My Headquarters staff, field office personnel, senior Fleet personnel, and I then critique these self-reviews, as appropriate.

Of course, the bottom-line measure of the success of the safety mechanisms is prevention of any event that could affect the health and safety of the public and Navy personnel or the environment. Therefore, we don't let near misses or even initiating events pass unchallenged. The hallmark of a strong safety culture is to look continually and actively address the minor problems in order to prevent the major problems.

Q2. The CAIB recommends a separation between the operational aspects of the Shuttle program and the organizations providing engineering and safety support. Based on your experience:

Q2a. Do you agree with this as a principle for managing your program?

A2a. In the Naval Nuclear Propulsion Program (NNPP), my Headquarters and Field Office staff that provides engineering and safety support also provides operational oversight (as opposed to operational control, which is assigned to the Fleet for ships and to the Prime Contractors for their laboratories and prototype reactors).

I do not agree with the principle of completely divorcing *all* operational aspects of a technical program from engineering and safety support for that program. The technical expertise from engineering and safety is necessary in the proper *oversight* of operations. Most importantly, I consider it vital for the technical authority to be one and the same as the safety oversight to ensure indepth and continuing understanding, awareness, and ownership of all aspects of design and operation.

For Fleet operations, Headquarters and Field Offices are responsible for the engineering and safety aspects relating to nuclear power. The Fleet operates the nuclear-powered warships in accordance with the safe operating procedures my organization provides them. The Prime Contractors operate prototype propulsion plants, following similar procedures. Changes to technical standards or operational procedures require my Headquarters' approval.

Q2b. Where do you place the boundaries between these three program elements in your program and how do they interact?

A2b. Within my organization, safety is the responsibility of everyone at every level: equipment suppliers, contractors, laboratories, shipyards, training facilities, the Fleet, field offices, and Headquarters. It is not a responsibility unique to a segregated safety department that then attempts to impose its oversight on the rest of the organization. Put another way, safety is mainstreamed. I expect to be able to ask any of my direct reports about the safety significance of any action in which they are involved and have them be able to explain the issues and why the action is satisfactory.

Because of the mainstreaming philosophy, some elements of the Program (such as shipyards and the Fleet) do not even have a separate reactor safety department. However, I do have a small group of people responsible for reactor plant safety analysis, who provide policy oversight as well as most of the liaison with other safety organizations (such as the NRC) to help ensure that we are using best practices. They also maintain the documentation of procedures and responsibility for the modeling codes used in our safety analyses. They are full-time safety experts who provide our corporate memory of what the past problems were, what we have to do to maintain a consistent safety approach across all projects, and what we need to know about civilian reactor safety practices. In addition, this group is part of our technical reviews to ensure that our mainstreamed safety practices are in fact working the way they should by providing an independent verification that we are not "normalizing" threats to safety.

While safety is mainstreamed throughout the Program, technical authority is vested in my Headquarters. Any other Program organization must get my Headquarters' agreement for any changes in technical standards and operational procedures. Sometimes this requires decisions that affect ship operations, which is one reason the Director of the NNPP needs to have a technical engineering background, with career-long experience in naval nuclear propulsion, and the seniority of a four-star admiral. Congress recognized this need and enacted it as a requirement in law.

Q2c. What training and experience do, you require, in your senior managers, and what incentives do you provide such managers?

A2c. Nearly all of my technical staff at Headquarters came to the NNPP right out of college and with science or engineering degrees. They receive NNPP-specific engineering training during their early years with the Program and continue to receive specialized training throughout their careers with us. At the end of their initial obligation, we offer permanent positions to those individuals who in our judgment have the requisite technical capabilities that best embrace our cultural values, such as mainstreaming safety. These are the people that go on to become my senior managers—a great many spending their entire adult lives and careers in the Program.

My section heads, the senior managers who report directly to me, have an average of more than 25 years of Program experience. However, mere longevity is not a requirement: a suitably capable individual with less time in service could become a section head. I select the best-qualified personnel as my senior managers.

As a performance measure, safety is not tied to incentives. Rather, it is a shared value among all engineers within the NNPP. My engineers won't be promoted to senior positions unless they demonstrate that they have embraced the importance of safety in their work and have ingrained this attitude in their subordinates, including fairly and completely vetting dissenting opinions.

Threats From Minor Problems

Q3. In both Shuttle accidents, NASA failed to appreciate the threat to the vehicle from what seemed a minor problem—O-ring seals that did not seem to work well

in cold weather and foam that sometimes struck the Orbiter's thermal protection system.

Q3a. How does your organization deal with similar "weak signals"?

A3a. In a high-risk environment, there are no guarantees of success, but our record demonstrates the value of hard work in addressing the "weak signals." As an organization, we do not allow weak signals to go unanswered. An important part of our technical effort is working on small problems to prevent bigger problems from occurring. We measure and track minor deficiencies to identify trends. Then we ask the hard questions on even apparently minor issues: *What are the facts? How do you know? Who is responsible? Who else knows about the issue and what are they doing about it? What other ships or activities (e.g., the labs or prototypes) could be affected? What is the plan? When will it be completed? Is this within our design, test, and operational experience? What are the expected outcomes? What is the worst that could happen? What are the dissenting opinions?* These and other questions like them help us to solve the problem at hand before it gets worse. As an example, I personally read letters (required at least quarterly) from each of the commanding officers of our 82 nuclear-powered warships. I look for these "weak signals" in their reports and flag them to cognizant headquarters personnel for resolution through this process. Additionally, my Headquarters and field organizations conduct periodic inspections in the field to determine the effectiveness of the individual activities in identifying, assessing, and resolving such deficiencies.

Q3b. How does your organization evaluate problems to determine if they represent recurring failures that require changes in design or processes if they are to be dealt with? Who conducts those evaluations?

A3b. Even minor problems under Headquarters' consideration require formal and disciplined review, together with official action and resolution correspondence signed by the cognizant Headquarters engineers. Any issue that, in our view, could recur and have undesirable consequences is assessed for the need for corrective action by my Headquarters staff. Where my staff concludes that action is warranted, I task the prime contractor laboratories with further assessment and with recommending corrective action. If the issue is time-sensitive, the Naval Nuclear Propulsion Program (NNPP) will immediately issue guidance by naval message to any ships or in writing to any training reactors that may be affected.

Q3c. For recurring problems, does your organization have the capability to analyze the trend to determine if it could contribute to a low-probability, high-consequence accident?

A3c. The Naval Nuclear Propulsion Program (NNPP) conducts extensive self-audits and performs various analyses of trends. Multiple organizations (my Headquarters organization, Nuclear Propulsion Examining Boards, Fleet headquarters, type commanders, naval squadrons, shipyards, and laboratories) are notified when problems arise and can call for further evaluation and correction based on recognition of a trend or precursor event requiring correction. Put simply, recurring problems aren't "normalized." We do everything we can to engineer them out of our system *before* they become major issues.

Q3d. How much certainty would your organization require to take action in a case where your relevant technical expert strongly believed a catastrophe could occur but did not have the engineering evaluations to confirm that judgment—and little or no time to conduct such evaluations?

A3d. To determine the relative importance of individual discrepancies, I rely on my engineering judgment and that of my experienced managers and engineers throughout the Program. If there were a strong belief, even if only by a single individual, those unacceptable consequences are a possibility, the issue would be attacked at: the technical level by my DOE labs and Headquarters experts and then discussed with me. All relevant technical facts would be presented, and an appropriately conservative course, balanced by military necessity, would then be chosen. This would not always mean that the reactor, and therefore the ship, must stand down from operation, but it might require additional operational precautions that suitably offset the situation under consideration. The Director, as a four-star admiral with a career of nuclear experience and a long tenure (the law stipulates eight years), is essential to making this come out right. Engineering is not an exact process—there is no single absolutely correct answer to every problem. The NNPP, as instituted by Admiral Rickover and as it continues to this day, embraces the philosophy that airing dissenting opinions helps invigorate the technical evaluation process and minimize the chance that a technically significant issue is overlooked.

Question submitted by Representative Bart Gordon

Operational and Developmental Safety Structures

Q1. Does it matter in your organization whether a vehicle or product is deemed "operational" versus "experimental/developmental"? Do you have a different safety structure for operational activities versus those that are developmental in nature?

A1. Our safety structure and processes are independent of the operational designation of the product. However, the margin of conservatism will be even greater when we are dealing with a developmental system. We test components, subsystems, and then systems (often to the point of failure in tests prior to ships' use), to ensure that unexpected results are minimized in operational warships. We then thoroughly test the ships and crew pier side to confirm the acceptability of the systems and the training of the crew. When I take a ship to sea for the first time, on sea trials in which I directly participate, I confirm that both the propulsion plant and crew are fully capable and ready to join the Fleet. Once a ship is in commission, it is deemed "operational"—regardless of whether it is the first or the last of a class.

Questions submitted by Representative Nick Lampson

Safety at Every Level

Q1. Admiral Bowman testified that, "Safety is the responsibility of everyone at every level in the organization," a sentiment echoed by Ms. Grubbe in her statement—but in day-to-day program activities, safety is not a primary metric for measuring performance. Safety usually becomes an issue only after it is clearly seen to be absent. What specific actions *does your organization take to maintain the focus on safety when the pressures to achieve organizational goals inevitably build?*

A1. Safety is an overarching organizational goal. We recognize that the ability of the Navy to operate nuclear-powered warships in over 150 ports of call in more than 50 countries around the world is based on the trust we have earned and maintained by safely steaming over 129 million miles. If we do not deliver and maintain safe naval nuclear propulsion plants, we have failed our crews, our Navy, and our country. Everyone in the Naval Nuclear Propulsion Program (NNPP) understands this. We all understand (and are trained in this from our first day in the NNPP) that the only acceptable answer is the technically correct solution. We also recognize that no technology is risk-free. We benchmark actions against requirements and past practices, require that a design or change be proven technically correct, and identify any alternatives. If the only technically safe acceptable action is one that affects cost and schedule to an extent that cannot be accommodated within available resources or schedule, we slow the schedule and/or add the additional resources.

Additionally, the very fabric of my Headquarters organization ensures that safety is mainstreamed for the long haul. Headquarters personnel are handpicked and have a common broad heritage of technical Program training and experience that permit the necessary esprit de corps and shared values. These factors (together with the independence of our technical authority from others in the Navy who are primarily charged with "cost, schedule, and mission") permit us to provide effective direction and oversight. Safety is not just a way to measure performance: it's the result of a process that must be followed from start to finish if we are to achieve the desired result.

Technical Authority and Safety Assurance

Q2. In your organization, do you have units performing the functions of an independent technical authority and office of safety assurance? How do they interact within your organization? If you don't, why not?

A2. In my DOE "hat," my Headquarters is the absolute technical authority for all naval reactor plants. Therefore, any other organization must get my Headquarters' agreement for any changes in technical standards and operational procedures. Sometimes this requires decisions that affect ship operations, which is one reason the director of the Naval Nuclear Propulsion Program (NNPP) needs the seniority of a four-star admiral. Congress recognized this need and enacted it as a requirement in law.

I don't separate technical authority and safety assurance. They are part and parcel of the same process. For the Navy, my organization is responsible for the engineering and safety aspects relating to nuclear power. The Fleet operates the nuclear-powered warships in accordance with safe operating procedures my organization provides them. In the NNPP, the same staff that provides engineering and safety support also provides operational oversight (as opposed to the Fleet's operational control). Safety is the responsibility of everyone at every level of the Program. In other words, safety is mainstreamed. It is not a responsibility unique to a segregated safety department that then attempts to impose its oversight on the rest of the organization. This is the only way safety can be ensured effectively, since no separate office of safety can have the depth of technical knowledge and personnel resources to cover an entire, complex technical program in the detail necessary to fulfill a safety responsibility.

Although the various elements of the Program (such as shipyards and the Fleet) do not have a separate reactor safety department, I do have a small group of people responsible for reactor plant safety analysis. They provide policy oversight as well as most of the liaison with other safety organizations (such as the Nuclear Regulatory Commission) to help ensure that we are using best practices. They also maintain the documentation of procedures and upkeep of the modeling codes used in our safety analyses. As full-time safety experts, they provide our corporate memory of what the past problems were, what we have to do to maintain a consistent safety approach across all projects, and what we need to follow in civilian reactor safety practices. By providing an independent verification that we are not "normalizing" threats to safety, each additional group involved in a technical review also ensures that our mainstreamed safety practices are in fact working the way they should.

Questions submitted by Representative Sheila Jackson Lee

Safety Training and Awareness

Q1. How is safety training done in your organization? How is safety awareness maintained in your organization? Please describe the kinds of training materials you use.

A1. Allow me to break my answer into elements dealing with my Headquarters and the U.S. Navy Fleet.

Safety awareness is built into every part of our work, including our extensive training programs. Thorough training minimizes problems, results in quick and efficient responses to issues, and helps ensure safety. At my Headquarters, I select the best graduate engineers I can find, with the highest integrity and the willingness to accept complete responsibility for every aspect of nuclear-power operations. After I hire them, the training they need to be successful begins immediately. All members of my technical staff undergo a technical indoctrination course during their first several months at Headquarters. Next, they spend two weeks at one of our training reactors (prototypes), learning about the operation of the reactor and observing and participating in the training our Fleet sailors are undergoing. This involves an actual, operating reactor plant, not a simulation or a PowerPoint presentation—and it is an important experience. It gives them an understanding that the work they do affects the lives of the sailors directly, while they perform the Navy's vital national defense role. This direct experience helps reinforce the tenet that the components and systems we provide must perform when needed.

Shortly after our new people return from the training reactor, they spend 6 months in residence at one of our DOE laboratories, completing an intensive, graduate-level course in nuclear engineering. Once that course is complete, they spend three weeks at a nuclear-capable shipyard, observing production work and work controls. Finally, they return to Headquarters and are assigned to work in one of our various technical jobs. They then attend a six-month series of seminars on a wide range of technical and regulatory matters, led by the most experienced members of my staff. Each of these training experiences is saturated with the principles of reactor safety through high quality assurance of plant material, conservative design, and verbatim adherence to procedures.

At Headquarters, there is a continual emphasis on professional development. We typically provide training courses that are open to the entire staff each month on various topics, technical and non-technical. In particular, we have many interactive training sessions on lessons we've learned—mistakes that we, or others, have made—in order to prevent similar mistakes in the future. These sessions teach both the specific issues and the right questions to ask.

Throughout their careers, the members of my staff are continually exposed to the end product, spending time on the waterfront, at the shipyards, in the laboratories, at the vendor sites, or interacting directly with the Fleet. In addition, the constant interaction among Headquarters personnel provides me with an arsenal of individuals who, though charged with responsibilities in specific areas, are capable and knowledgeable of overarching Program interests and are expected to act accordingly. Every one of these activities and perspectives emphasizes the vital role of safety.

My responsibilities also include training the operators of nuclear-powered warships. I require both officer and enlisted operators to undergo 6 months of formal academic instruction in nuclear propulsion theory and technology, followed by 24 weeks of hands-on operational and casualty training at an operating prototype or moored training ship (MTS). Even after completing this training and qualification as an operator at a prototype or MTS, personnel must completely requalify (including familiarization steps and watch standing under instruction) on the ship to which they are assigned before they are permitted to man a propulsion plant watch station on that ship. For both officer and enlisted nuclear-trained personnel, there is continuing training and required periodic requalification in the Fleet throughout their careers. My prime contractor personnel who operate the prototype reactors get equivalent training.

For the officers, a significant milestone in their career path is qualification as an engineer officer. This signifies an officer has obtained sufficient knowledge to supervise safe, effective maintenance and operation of the ship's propulsion plant. When the commanding officer (CO) is satisfied with a junior officer's knowledge level, he recommends him or her to take the Engineer's Examination. The Engineer's Examination is administered at my Headquarters and consists of a written examination (about five hours long) and at least two detailed technical interviews. I personally approve qualification of each engineer officer. The best of these junior officers are subsequently assigned to submarines as the engineer officer or to aircraft carriers as a principal assistant to the reactor officer.

The commanding officer (CO) is charged with the absolute responsibility for all aspects of ship operation, including safe and effective operation of the reactors. Personnel who become COs of nuclear-powered submarines are all Engineering Officer of the Watch qualified with about 17 years of experience in the Navy. They have qualified as an engineer officer on a nuclear-powered submarine, have served as an executive officer and have successfully completed an intense, technical/safety course during a three-month Prospective Commanding Officer School at Naval Nuclear Propulsion Program Headquarters.

The path for becoming a CO of a nuclear-powered aircraft carrier is similar. Personnel who become COs of a nuclear-powered aircraft carriers are Engineering Officer of the Watch qualified officers with over 20 years of experience in the Navy. They have completed a three-month Prospective Commanding Officer School at Naval Nuclear Propulsion Program Headquarters and have served as an executive officer on a nuclear-powered aircraft carrier.

Every segment of every training experience for both Headquarters and Fleet personnel emphasizes the absolute need for "safety first." Lessons learned from historical problems are discussed in detail. The conservative design of our plants and the need for strict adherence to written, formal procedure is taught and tested. There is no confusion regarding our philosophy that safety comes first.

Safety Audit Process

Q2. Please describe your safety audit process. What is its scope? How often is it done? Who does it? To whom, are the results reported? What is done with the results?

A2. My safety inspection process is extensive. Inspection and corrective action follow-up are essential aspects of being the technical authority for the Program and its current 103 reactor plants. Headquarters personnel at the most senior level personally evaluate performance and compliance in the field. Headquarters staff conducts regular inspections of work, safety, environmental and radiological controls. Additionally, field office personnel routinely conduct audits and inspections as part of their responsibility to monitor the work of Program laboratories, prototypes, the Fleet, shipyards, and prime contractors. The DOE laboratories, the nuclear-capable shipyards, and the Fleet also conduct self-audits, assessments, and inspections at almost every organizational level. These reviews are then critiqued by Headquarters, field office, and senior Fleet personnel (as appropriate) and then reported to me. An important part of these reviews is evaluating the activity's ability to look critically at itself—in keeping with the principle that each activity must identify, diagnose, and resolve its own problems when outside inspectors are not present to

do so. This effort, along with other requirements, makes clear that day-to-day excellent performance must be the goal (and the norm), not merely "peaking" for an annual audit or inspection. In fact, my evaluation teams make "inadequate self-assessment" a finding of its own, when appropriate. My teams will then closely follow the efforts of activity management to improve this crucial ability.

Headquarters evaluation teams always include the technical-requirements owners for the particular areas being assessed. This ensures that the team has an indepth understanding of not only the requirement, but also its significance, letting the evaluation team identify issues and trends that might not be discerned if auditing were done solely by checklist. My field offices, largely composed of qualified personnel drawn from the Fleet and from Headquarters, are located at all major Program sites and at each Navy Fleet concentration area.

The Naval Nuclear Propulsion Program (NNPP) continually evaluates operational information for trends and lessons learned. For example, my staff annually assesses—and I personally review plant-aging concerns to ensure that trends in equipment corrosion, wear, and maintenance performance are acceptable.

To meet regulatory responsibilities for oversight of nuclear-powered warship operations, the NNPP relies in part on the Nuclear Propulsion Examining Board (NPEB). The NPEB, comprising nuclear-trained officers who have served as commanding officers or engineer officers of nuclear-powered warships, performs annual Operational Reactor Safeguards Examinations (ORSE) and inspects the material condition of each plant in the Fleet. During an ORSE, the NPEB reviews documentation of normal operation (including operational, maintenance, and crew training records); observes and assesses current plant operations (both normal and in response to casualty drills); and reviews any off-normal events that may have occurred during the preceding year. The NPEB reports directly to me in parallel with the command authority for that ship (the Fleet Commander). As discussed above, the ship's day-to-day performance and ability to self-assess are emphasized through evaluation of records, training, evolutions, lessons learned, and overall plant conditions. If ships do not meet standards, they would have their authorization to operate removed until they are upgraded, reexamined, and deemed satisfactory.

Dissenting Opinions

Q3. In your organization, is there a channel specifically for dissenting opinions?

Q3a. How do you generate a dissenting opinion in a case where a strong technical consensus exists? What prevents that from becoming an empty exercise?

Q3b. How would a dissenting technical opinion be evaluated?

A3a,b. There are several channels through which individuals can air dissenting opinions. At my prime contractor laboratories, any dissenting opinion must be documented, along with a discussion of the reason why the majority opinion is being recommended. (In some cases the process results in the formerly "dissenting" opinion *becoming* the recommended approach.) In the case of a dissenting opinion that could affect safety, further analysis and discussion are required to attempt to reach a satisfactory resolution. If the dissenter is not satisfied, the recommended action must be agreed to by the laboratory general manager, and the dissenting opinion is documented in the recommendation to me with an explanation as to why it was not accepted. This allows my staff and me to see that dissenting opinion firsthand as we evaluate the recommendation.

Similarly, within Headquarters, if a dissenting opinion is not resolved, the issue must be cleared with me. When I discuss a complex issue, I frequently ask if there were any dissenting opinions to ensure that personnel have the opportunity to air any remaining concerns. If I am satisfied that I have enough data to make an informed decision, I will do so. In any other case, I will request additional information or the involvement of additional personnel to help me reach the correct technical decision.

Q3c. In cases where dissenting opinions question the safety of reactor operations for a ship (or class of ships) deployed and operating, are reactors immediately shut down or is a risk assessment performed to determine whether operations can continue?

A3c. Nuclear-powered warships are designed to survive under battle conditions. The inherent conservatism and redundancy built into these ships, along with the extensive training provided every operator, make it highly unlikely that any unexpected problem will pose an immediate threat to public or environmental safety. If such an unlikely problem ever were to occur, we would balance the multiple safety responsibilities of reactor, crew, ship, and public safety. Where there is a reactor safe-

ty concern, we immediately determine whether the problem is likely to occur, the potential consequences, its potential impact on ship operations and safety, and any alternatives that may mitigate the problem. Since our designs include significant redundancy, shutting down all or part of the reactor plant system of concern might still allow safe operation of the reactor. If necessary, the reactor would be shut down and the problem repaired, even at sea.

Q3d. While dissenting opinion may be welcomed in the Naval Reactors program, how do you demonstrate to new junior officers that expressing such opinions will not create problems for their careers in the Navy outside the program—particularly if that opinion is left unsupported by later analysis?

A3d. In the Fleet, dissenting opinions are raised through the chain of command. Dissenting opinions are not just welcomed, they are highly valued. For the Fleet, asking questions and raising concerns is highlighted during training for junior officers and enlisted personnel from their first day in the Program. In fact, we teach and require forceful backup. If expected indications and conditions are not observed during an evaluation, other members of the watch team are required to point that out. There cannot be any fear of reprisal for raising concerns or issues. The best proof of this is our record. I can't think of a single example when a junior officer brought up a safety issue and it created a problem for that officer's career. On the contrary, if an officer of any rank is aware of a safety issue and doesn't bring it up, that officer would be held accountable.

ANSWERS TO POST-HEARING QUESTIONS

Responses by Rear Admiral Paul E. Sullivan, Deputy Commander, Ship Design, Integration and Engineering, Naval Sea Systems Command, U.S. Navy

Questions submitted by Representative Ralph M. Hall

NASA Implementation of Investigation Board Recommendations; SUBSAFE Program Measures

Q1. How will we know that NASA has implemented the Columbia *Accident Investigation Board (CAIB) recommendations?*

A1. Respectfully, this question may be best posed to the CAIB, or similar independent board. As a practical matter, it is beyond the purview of the Naval Sea Systems Command (NAVSEA) to monitor NASA's implementation of the CAIB recommendations, and therefore, we are unable to offer a substantive response in this area. However, as noted in my testimony, NAVSEA is a continuing participant in the NASA/Navy Benchmarking Exchange. To that extent, we are engaged in the process of sharing information with NASA on all aspects of the Submarine Safety (SUBSAFE) Program, so that NASA itself can evaluate the potential adaptability of any part of the SUBSAFE Program to the NASA Safety Program.

Q1a. What measures do you use in your organization to determine that your safety mechanisms are working?

A1a. The Navy uses a tiered approach to ensure Submarine Safety (SUBSAFE) Program safety mechanisms are working. The Naval Sea Systems Command Submarine Safety and Quality Assurance Office (NAVSEA 07Q) has overall responsibility for overseeing the SUBSAFE Program and verifying compliance with its requirements.

- The purpose of the SUBSAFE Program is to provide maximum reasonable assurance of a submarine's watertight integrity and its ability to recover from a flooding casualty. It is important to note that the SUBSAFE Program does not spread or dilute its focus beyond this purpose. The technical and administrative requirements of the SUBSAFE Program are applied specifically to a carefully defined set of ship systems and components that are critical to the safety of the submarine. The tenets of the SUBSAFE Program are invoked in a submarine's initial design, through construction and initial SUBSAFE Certification, and throughout its service life.
- The first tier of the SUBSAFE Program is a Quality Program at each activity that performs SUBSAFE work. Each facility is required to have a quality system such as that defined by MIL–Q–9858 (Quality Program Requirements) or ISO 9000, etc. The quality assurance organization at each facility plays a key role in validating compliance with SUBSAFE Program requirements and in compiling the objective quality evidence necessary to support SUBSAFE certification. A local SUBSAFE Program Director (SSPD) provides oversight for work at each facility and is responsible for independently verifying compliance with the SUBSAFE Manual requirements. At private contractor shipbuilding facilities, a U.S. Navy Supervisor of Shipbuilding, Conversion and Repair (SUPSHIP) organization is also assigned to monitor compliance with SUBSAFE work and process requirements.
- The second tier is the SUBSAFE audit program. NAVSEA 07Q audits the policies, procedures and practices at each facility as well as the effectiveness of the oversight provided by the local SSPD and SUPSHIP. There are two types of audits: (1) the *Functional Audit,* which evaluates the organization's programs and processes for compliance with SUBSAFE requirements; and (2) the *Ship Certification Audit,* which evaluates the work and processes used to overhaul or construct each individual submarine for compliance with SUBSAFE requirements prior to SUBSAFE certification.
- The final tier is program oversight. Several organizations provide forums for program evaluation, process improvement, and senior level oversight. The *SUBSAFE Working Group,* chaired by the Director of the Submarine Safety and Quality Assurance Office (NAVSEA 07Q), is comprised of NAVSEA, field activity and contractor SSPDs and meets semi-annually to review program status and discuss recommendations for improvement. The *SUBSAFE Steering Task Group,* chaired by the NAVSEA Deputy Commander for Undersea Warfare (NAVSEA 07), reviews program progress and provides policy guid-

ance for the SUBSAFE Program. The *SUBSAFE Oversight Committee,* chaired by the NAVSEA Vice Commander (NAVSEA 09), provides independent command-level oversight of the SUBSAFE Program to ensure the purpose and intent of the SUBSAFE Program are being met.

Separation Between Operational Aspects of Program and Organizations Providing Engineering and Safety Support

Q2. The CAIB recommends a separation between the operational aspects of the Shuttle program and the organizations providing engineering and safety support. Based on your experience:

Q2a. Do you agree with this as a principle for managing your program?

A2a. Yes. The separation of Program Management, the Technical Authority, and the Safety Organization has proven an effective approach for the Navy's Submarine Safety (SUBSAFE) Program during the last 40 years.

Q2b. Where do you place the boundaries between these three program elements in your program and how do they interact?

A2b. The three groups—Program Management, Technical Authority, and Safety Organization—work together to discuss issues and reach agreement on final decisions. However, each has its own authority and responsibility:

- The Program Manager has overall authority and responsibility for the success of his program (Quality, Cost, Schedule). However, the Program Manager is not a technical authority and may not make technical decisions unilaterally. The Program Manager has the authority to choose among the technically acceptable solutions provided by the Technical Authority.
- The Technical Authority bears ultimate responsibility for the adequacy of the technical solutions provided to the Program Manager.
- The Safety Organization has the authority and responsibility to ensure that compliance with SUBSAFE Program requirements is achieved. The Safety Organization is staffed with engineers giving it the acumen to understand the technical issues and providing it with the credentials to challenge the Technical Authority and the Program Manager when appropriate.

Q2c. What training and experience do you require in your senior managers, and what incentives do you provide such managers?

A2c. Senior managers are hand picked based on detailed submarine experience. Senior managers receive continuous training on safety and participate in the audit process. Our senior managers, military and civilian, are required to achieve a broad scope of experience and formal training as they progress in their career. Both the Navy and the Office of Personnel Management establish supervisory and management training programs to enhance career paths and assist in developing the knowledge, skills and abilities necessary to achieve success in the senior management levels of the Naval Sea Systems Command (NAVSEA) and the Navy.

Recognition and Analysis of Safety Threats

Q3. In both Shuttle accidents, NASA failed to appreciate the threat to the vehicle from what seemed a minor problem—O-ring seals that did not seem to work well in cold weather and foam that sometimes struck the Orbiter's thermal protection system.

Q3a. How does your organization deal with similar "weak signals"?

A3a. Dealing with and resolving "weak signals" before they become major problems, or even disasters, is very difficult for a large organization. It requires constant vigilance. These signals get missed when people become complacent and accept seemingly minor unsatisfactory conditions. As I noted in my testimony, our review of the Submarine Safety (SUBSAFE) Program during the 1985–86 timeframe noted an increasing number of incidents and breakdowns that raised concerns about the quality of SUBSAFE work and thus, the level of discipline with which that work was being performed. As a result, we established additional program requirements and actions to improve the understanding of SUBSAFE Program requirements, to provide increased emphasis on oversight, and to find problems and fix them. They are still in place today, but personal vigilance is still required as the potential exists for complacency to creep into any organization. For example, less than two years ago, we nearly lost the USS DOLPHIN (AGSS 555) to a flooding casualty. While it was not

a SUBSAFE issue, the casualty was due, in part, to allowing a less than acceptable condition to exist that made it easier for water to enter the submarine when transiting on the surface. Only the skills and exceptional action on the part of the well-trained crew prevented disaster. Although crew selection and training aren't part of SUBSAFE, the Navy gives them the appropriate level of attention to ensure the crews are highly trained, competent and motivated. Corrective and other follow-up actions are still in progress from the incident.

Q3b. How does your organization evaluate problems to determine if they represent recurring failures that require changes in design or processes if they are to be dealt with? Who conducts those evaluations?

A3b. We have several formal programs for evaluating failures and conditions that may require program or design changes. Periodic inspections and tests are required to be performed to validate that the condition of the submarine and its critical components support continued unrestricted operation. The results of these inspections and tests are tracked over time and across submarines to ensure conditions are not degrading. During component major maintenance or overhaul, the conditions found must be documented and reported for technical evaluation, again, to determine if any unexpected degradation may be occurring and to maintain a history, that is used to evaluate the need for maintenance program or design changes. Audits of facilities and submarines are conducted to evaluate performance and acceptability of a submarine for SUBSAFE certification. During the service life of a submarine and facility, problems or failures may occur that are outside the scope of the formal inspection and audit programs. These are required to be formally investigated and reported to Naval Sea Systems Command (NAVSEA) as Trouble Reports. The results of audits and Trouble Reports are tracked, maintained and trended over time, and are used to evaluate the health of program and determine if changes are required or appropriate to consider. Responsibility for these programs, including implementation of changes, is assigned to specific offices or organizations within NAVSEA. However, recommendations for significant changes in technical requirements or program procedures are reviewed and concurred with by members of the Technical Authority, Program Manager and Safety Offices.

Q3c. For recurring problems, does your organization have the capability to analyze the trend to determine if it could contribute to a low-probability, high-consequence accident?

A3c. Trending and analysis are an integral part of the Submarine Safety (SUBSAFE) Program and are used to guide future actions. In addition, an annual SUBSAFE Program assessment is prepared with input from SUBSAFE Working Group members, and is briefed to the SUBSAFE Steering Task Group and the SUBSAFE Oversight Committee. Hazard analyses of specific conditions or component or system operations are conducted when warranted to assess risk and potential consequence, and to determine what actions must be taken to mitigate risk if the condition is to be allowed to exist.

Q3d. How much certainty would your organization require to take action in a case where your relevant technical expert strongly believed a catastrophe could occur but did not have the engineering evaluations to confirm that judgment—and little or no time to conduct such evaluations?

A3d. When we identify a significant technical/safety concern, the normal approach is to suspend work, testing, or ship deployment until the relevant engineering evaluations are obtained. For a significant and imminent wartime condition or situation, a risk assessment would be presented to the Fleet Type Commander for decision.

Questions submitted by Representative Bart Gordon

Operational vs. Developmental Safety Structure

Q1. Does it matter in your organization whether a vehicle or product is deemed "operational" versus "experimental/developmental"? Do you have a different safety structure for operational activities versus those that are developmental in nature?

A1. No, Submarine Safety (SUBSAFE) Program requirements are invoked in design contracts and construction contracts, including those for experimental or developmental items placed on our submarines. The SUBSAFE Program structure is the same whether an item is operational or developmental.

Dealing with Downsizing and Aging Workforce Challenges

Q2. You mentioned in your written testimony the challenge you faced in 1998 with downsizing and an aging workforce. Please describe the magnitude of the problem and the steps you took to maintain the integrity of the SUBSAFE Program in the face of this challenge? How are you dealing with these problems?

A2. Over the past decade, the Naval Sea Systems Command (NAVSEA) has undergone a significant loss of experience and depth of knowledge due to downsizing and an aging workforce. The size of the independent technical authority staff at NAVSEA headquarters has been reduced from 1300–1400 people in 1988 to approximately 300 today. Beginning in 1995, NAVSEA undertook an approach to provide continued support of critical defense technologies with a smaller Headquarters workforce. This was accomplished through the development of a war-fighting system engineering hierarchy that defined the necessary engineering capability requirements. NAVSEA began to refocus our workforce on core equities or competencies:

- Setting technical standards and policies,
- Certifying and validating delivered products, and
- Providing a vision for the future, i.e., technology infusion and evolution.

NAVSEA also initiated a recruitment program to hire engineering professionals, primarily in our field activities, but headquarters engineering staff continued to decrease.

As a result of the noted reduction in NAVSEA headquarters independent technical authority staff over the past 15 years, we have remained continuously engaged in balancing the need to maintain our culture of safety while becoming more efficient.

NAVSEA currently is contemplating modest increases in staffing in the independent technical authority and SUBSAFE and quality assurance organizations to manage the increasing SUBSAFE workload in design, construction and maintenance, and to bolster and renew the workforce as our older experts retire.

Questions submitted by Representative Nick Lampson

Specific Actions to Maintain Focus on Safety

Q1. Admiral Bowman testified that, "Safety is the responsibility of everyone at every level in the organization," a sentiment echoed by Ms. Grubbe in her statement—but in day-to-day program activities, safety is not a primary metric for measuring performance. Safety usually becomes an issue only after it is clearly seen to be absent. What specific actions *does your organization take to maintain the focus on safety when the pressures to achieve organizational goals inevitably build?*

A1. First, Admiral Bowman and Ms. Grubbe are correct. The culture of safety must be instinctive. Training, instructions and written performance requirements are not enough to ensure safety. In the final analysis, each person who operates, designs, constructs, maintains or tests submarines must have the culture of safety as part of his or her basic work ethic. This culture is instilled in our sailors from the first day of submarine basic training, and in the civilian workforce by continuous grooming from their leaders. It is reinforced for all by periodic mandatory Submarine Safety (SUBSAFE) training.

Second, we cannot afford for safety to become "absent" and we work constantly to ensure that does not happen. We do that by keeping the requirements of our Submarine Safety (SUBSAFE) Program visible at all levels. Critical safety requirements and implementation methods are clearly defined. These safety requirements are protected regardless of pressures. Program Managers cannot tailor them or trade them against other technical or programmatic variables. The Technical Authority and the Safety Office do not compromise the technical or safety requirements to relieve a Program Manager's schedule or cost pressures. This separation of Program Management, the Technical Authority and the Safety Office has proven to be an effective organizational structure in support of Submarine Safety. Our routine SUBSAFE training includes lessons learned with strong emotional ties. Our SUBSAFE audit programs focus on technical and safety compliance and provide additional visibility to the importance of safety.

Finally, for the U.S. Navy Submarine Force, safety IS an organizational goal. It is tracked carefully and reviewed frequently by senior management, and corrective action is rapid.

Lessons from the Challenger Accident

Q2. What lessons does the Navy take away from its review of the Challenger *accident?*

A2. As noted in my testimony, the *Challenger* accident occurred at the same time the Naval Sea Systems Command (NAVSEA) was conducting an in-depth review of the Submarine Safety (SUBSAFE) Program. The *Challenger* accident gave added impetus to, and helped focus our effort in, several critical areas: disciplined compliance with requirements, thoroughness and openness of technical evaluations, and formality of our readiness for sea certification process.

As a result of our review, we have: maintained increased visibility on mandatory and disciplined compliance with requirements and standards; upgraded our engineering review system (technical authority) to ensure responsibilities and expectations for thorough engineering reviews with discipline and integrity are clear; and established a safety and quality assurance organization with the authority and organizational freedom to function without external pressure. We use annual training with strong, emotional lessons from past failures to ensure that all members of the Navy's Submarine community fully understand the need for constant vigilance in all SUBSAFE matters.

NASA/Navy Benchmarking Exchange

Q3. Please provide your impression of the NASA/Navy Benchmarking Exchange (NNBE) undertaken in August of 2002. What specific plans, if any, are there for continuing this interaction? What changes in this interaction do you anticipate because of the Columbia *accident?*

A3. The NNBE has been a valuable process for both NASA and the submarine Navy. Two reports outlining the results of the NNBE to date have been issued, the first in December 2002 and the second in July 2003. After the loss of *Columbia,* NNBE activity was temporarily placed on hold to allow NASA to focus on the accident investigation. Specific exchanges under the NNBE process since the *Columbia* accident have included Navy presentations to the NASA Engineering and Safety Center Management Team and to the SUBSAFE Colloquium held at NASA headquarters in November 2003. On December 2, 2003, both parties signed a Memorandum of Agreement for participation in engineering investigations and analyses. A Memorandum of Agreement for participation in Functional Audits is currently being developed and is scheduled to be signed in early 2004. In the NNBE forum, we have initiated exchanges regarding processes for specification control, waivers to requirements, life cycle extension, software safety and human systems integration. More detailed discussions on these common processes are planned in 2004. We also expect benefits from planned collaboration of technical experts in welding, materials, life support and other areas of special interest.

Questions submitted by Representative Sheila Jackson Lee

Safety Training

Q1. How is safety training done in your organization? How is safety awareness maintained in your organization? Please describe the kinds of training materials you use.

A1. The Submarine Safety (SUBSAFE) Manual requires that organizations performing SUBSAFE work establish and maintain procedures for identifying training needs and provide for the training of all personnel performing activities affecting SUBSAFE quality. This requirement includes periodic SUBSAFE Awareness training. During Functional Audits of these organizations we evaluate the adequacy of training programs and the level of knowledge of personnel performing SUBSAFE work. Our SUBSAFE requirements are generally integrated into specific technical process or work-skill training. This training and its periodicity are established and provided by each organization to meet its needs for the work it performs.

One of the keys to SUBSAFE Program awareness is the fact that many of the senior Navy and civilian managers and personnel have either served aboard or temporarily embarked on submarines during their careers. This "underway" experience, in addition to regular visits to submarines undergoing construction, repair or maintenance, fosters a heightened level of understanding in program management that is important to maintaining the requisite level of vigilance and visibility for SUBSAFE matters.

SUBSAFE Program Awareness Training is usually given on an annual basis. It consists of a review of requirements, a brief history of the SUBSAFE Program and a discussion of recent relevant program events, e.g., changes, problems, and failures (and their causes). SUBSAFE training beyond the annual awareness training takes a variety of forms. Web-based training is becoming the most common. This is supported by classroom lecture and discussion. Skills-training takes the same form and is supplemented by practical exercises and on-the-job training. By combining personal experience, training and our requirements in this way, we keep the SUBSAFE Program and its requirements visible to and fresh in the minds of the Navy's Submarine community personnel, ashore and afloat.

Safety Audit Process

Q2. Please describe your safety audit process. What is its scope? How often is it done? Who does it? To whom are the results reported? What is done with the results?

A2. There are two primary types of audits in the Submarine Safety (SUBSAFE) Program: Certification Audits and Functional Audits.

In a SUBSAFE Certification Audit, we look at the Objective Quality Evidence associated with an individual submarine to ensure that the material condition of that particular submarine is satisfactory for sea trials and unrestricted operations. These audits are performed at the completion of new construction and at the end of major depot maintenance periods. They cover a planned sample of specific aspects of all SUBSAFE work performed, including inspection of a sample of installed equipment. The results and resolution of deficiencies identified during such audits become one element of final Naval Sea Systems Command (NAVSEA) approval for sea trials and subsequent unrestricted operations.

In a SUBSAFE Functional Audit, we periodically—either annually or bi-annually depending on the scope of work performed—review the policies, procedures, and practices used by each organization, including contractors, that performs SUBSAFE work. The purpose is to ensure that those policies, procedures and practices comply with SUBSAFE requirements, are healthy, and are capable of producing certifiable hardware or design products. This audit also includes surveillance of actual work in progress. Organizations audited include public and private shipyards, engineering offices, the Fleet, and NAVSEA headquarters.

Audits are performed by a team of 12 to 25 auditors, led by the NAVSEA Submarine Safety and Quality Assurance Office (NAVSEA 07Q). Auditors are experienced subject matter experts drawn from NAVSEA and our field organizations that perform SUBSAFE work, e.g., shipyards, engineering offices, etc. To ensure consistent and thorough coverage of the areas of concern, audits are conducted using formal audit plans or guides. In functional audits, guides are supplemented with pre-audit analysis reports,

that assess the prior health of the organization and point out past problems so that the effectiveness of corrective actions can be evaluated. The results of audits are formally documented and reported to the organization and to senior NAVSEA management. They are also provided to other SUBSAFE organizations for lessons learned purposes. Each deficiency must be corrected and the root cause of the deficiency identified. The corrective action and root cause is formally reported back to NAVSEA along with applicable objective quality evidence for evaluation and approval. Further, each deficiency is tracked by NAVSEA 07Q to maintain its visibility and to ensure it is satisfactorily resolved. Annually, an analysis report of all audit results, and other reported problems, is prepared to support a senior management assessment of the health of the SUBSAFE Program.

Functional Audits are also used to identify areas in which an organization can initiate process improvements. Although a process or practice may be in compliance with SUBSAFE requirements, auditors may make recommendations, which offer the opportunity for significant improvement in the effectiveness of the process or practice. These recommendations, categorized as *Operational Improvements,* are documented in the report and tracked until the organization provides its evaluation and any planned actions.

In addition to the audits performed by NAVSEA, our shipyards, field organizations and the Fleet are required to conduct internal (or self) audits of their policies, procedures, and practices and of the work they perform.

ANSWERS TO POST-HEARING QUESTIONS

Responses by Ray F. Johnson, Vice President, Space Launch Operations, The Aerospace Corporation

Note of Clarification: Throughout the discussions of CAIB investigations, the term "safety" is used relative to establishing NASA flight readiness. Since our DOD launches are not human rated, we use the term "mission assurance" in essentially an equivalent meaning. For DOD launches, the term 'flight safety" is primarily associated with the risks to the uninvolved public due to catastrophic failure rather than mission success itself.

Questions submitted by Representative Ralph M. Hall

Q1. How will we know that NASA has implemented the Columbia *Accident Investigation Board (CAIB) recommendations? What measures do you use in your organization to determine that your safety mechanisms are working?*

A1. Following the Space Launch Broad Area Review in 1999, the Air Force developed an execution plan for each of the Board's recommendations. Periodically since then the BAR has reconvened and reviewed progress against their initial recommendations. We would recommend a similar approach to track NASA's implementation of the CAIB recommendations.

Our mission success record is the best gauge of our mission assurance processes. Since the Broad Area Review, the renewed rigor in mission assurance has yielded a 100 percent success rate. We have also measured our success rate against other launch organizations (i.e., commercial, foreign) and found that our processes have consistently resulted in a higher level of success.

Q2. The CAIB recommends a separation between the operational aspects of the Shuttle program and the organizations providing engineering and safety support. Based on your experience:

Q2a. Do you agree with this as a principle for managing your program?

A2a. Our organization and the value of our contributions comes from the degree of independence we are afforded by our Air Force sponsors. Our launch programs do not employ separate organizations for safety, engineering and operations, but rather a triumvirate of program participants (Air Force, contractor, Aerospace) with individual responsibilities. Aerospace is the program participant with responsibility for the independent mission assurance assessment.

Q2b. Where do you place the boundaries between these three program elements in your program and how do they interact?

A2b. Our independent mission assurance role uses a cadre of engineering talent with skills comparable to that of the contractor who has the primary engineering and operational responsibility. Aerospace provides a final launch readiness verification to the SMC Commander that is independent from the contractor's assessment. The SMC Commander, in his role as ultimate flight worthiness certification authority, employs an additional oversight review team to ensure that the program participants properly execute their responsibilities.

Flight safety is the responsibility of the Range Safety organization at the launch sites. Range Safety is not only completely separate from the launch system program, it is under a separate Air Force organization. Range Safety's primary role is to protect resources, personnel, and general public from the hazards of launch.

Q2c. What training and experience do you require in your senior managers, and what incentives do you provide such managers?

A2c. We are essentially an engineering and scientific organization and our role in space launch does not typically require formal certification training of our personnel. Our engineering staff is made up of career professionals who typically have many years experience either in industry or academia. Many of these are the foremost specialists in their fields. Our senior managers (up to and including our president) all have strong technical backgrounds as well. Our field site personnel, who are associated with vehicle operations and exposed to hazardous conditions, are certified as required by the local safety organizations. We are incentivized by our accountability to mission success as well as formal recognition through a corporate awards program.

Q3. In both Shuttle accidents, NASA failed to appreciate the threat to the vehicle from what seemed a minor problem—O-ring seals that did not seem to work well in cold weather and foam that sometimes struck the Orbiter's thermal protection system.

Q3a. How does your organization deal with similar "weak signals"?

A3a. We apply rigor in defining system performance specifications and a continuous oversight presence in identifying any out-of-family condition following every launch. Any out-of-family deviation is thoroughly evaluated to determine the associated risk and corrective action.

Q3b. How does your organization evaluate problems to determine if they represent recurring failures that require changes in design or processes if they are to be dealt with? Who conducts those evaluations?

A3b. Each flight is thoroughly analyzed by domain experts to identify any anomalies. These anomalies are compared to other missions to evaluate trends and out-of-family performance. Each item is then assessed for mission risk and corrective action is established. Unless the risk can positively be established as low, the corrective action is made a lien against the next launch of that system. These evaluations are performed by the contractor and independently by Aerospace using separately acquired, processed, and analyzed telemetry, video and radar data. Results and findings are compared at formal Post-Flight Reviews.

Q3c. For recurring problems, does your organization have the capability to analyze the trend to determine if it could contribute to a low-probability, high-consequence accident?

A3c. Yes, we not only have the capability to independently analyze these conditions, we have the obligation to ensure they are accomplished. We maintain a separate database of launch vehicle flight data that our engineering team uses to maintain recurring flight records. We have also developed unique analytical tools for the engineers to use in analyzing and identifying trends. We recently identified a potential problem during trend analysis of actuator performance that was ultimately traced to internal contamination. Due to the consequences of failure from debris migration, all actuators of like manufacture were processed through a new cleaning procedure before another flight was allowed.

Q3d. How much certainty would your organization require to take action in a case where your relevant technical expert strongly believed a catastrophe could occur but did not have the engineering evaluations to confirm that judgment—and little or no time to conduct such evaluations?

A3d. We believe that we are required to take the necessary time to validate a condition such as this and would request the launch be held if need be. Our first obligation is to validate the concern through our readiness review process, then elevate in time to effect the launch decision. A recent example illustrates our process. Our experts identified a concern for dynamic instability on an upcoming Titan launch. This was based on observations noted on other launches but could not be readily quantified for this mission. Due to the risks involved, we requested a launch slip of several weeks while additional modeling was developed and analyses performed. The Air Force was persuaded by the preliminary analysis that a more definitive answer was warranted and delayed the launch. The results of this analysis created sufficient concern that flight changes were made that successfully mitigated the risk of occurrence.

Questions submitted by Representative Bart Gordon

Q1. Does it matter in your organization whether a vehicle or product is deemed "operational" versus "experimental/developmental"? Do you have a different safety structure for operational activities versus those that are developmental in nature?

A1. Space Launch is an inherently engineering intensive activity. This is partly due to the high performance, low margins, numerous hazards, and consequences of failure. But it is also due to the very low production and flight rates with equally low repeatability and assembly before flight. By any comparison to other transportation media, space launch operations would not be considered an operational system and its inherent reliability viewed as relatively low. Therefore as a space organization we have no truly operational systems and continuous engineering involvement is mandatory for mission assurance.

As mentioned in response to Mr. Hall's questions, Range Safety is responsible for flight safety of our launches. When a vehicle strays from its intended flight path, it is destroyed to protect the public from an errant vehicle. This approach would unlikely be employed in an operational transportation system. Also, a comparison of flight safety procedures for space launch and air traffic control yields many significant differences which can be attributed to the non-operational nature of launch.

Q2. In your written testimony you noted that a root cause of some launch failures in National Security Space programs was "the lack of disciplined system engineering in the design and processing of launch vehicles exacerbated by a premature dismantling of government oversight capability.. . ."

Q2a. Could you elaborate on the circumstances of this "premature dismantling" and how it contributed to the launch failures studied in the Broad Area Review?

A2a. The Broad Area Review found that a combination of budget reductions and program reforms that occurred in the early-mid 1990s converged to dilute program effectiveness. Pressures to reduce costs resulted in reduction of government oversight, quality assurance, erosion of expertise, and emphasis on cost savings over mission assurance. In addition specs, standards, and policies were abandoned and the mission assurance technical focus eroded in favor of an "operational" orientation. This was particularly true on Titan, one of the most complex launch systems in use, where manpower reductions in the government and Aerospace staff approached 50 percent. The Broad Area Review referred to this as a "premature going out of business mindset" in anticipation of flying out the remaining vehicles as the new EELV families were in development, whereas, in reality, the Titan launch rate was increasing. The Broad Area Review also found that the recent failures it examined could be attributed to engineering and workmanship (i.e., human) errors that should have been avoidable.

Q2b. How similar are the findings and conclusions of the Broad Area Review and the Columbia *Accident Investigation Board report?*

A2b. In both reviews it was found that lines of responsibility, accountability, and authority were fragmented, which resulted in an inadequate decision process. We also see similarities in findings that the government entity relied more and more on the contractor, allowed organic capabilities to erode, and became more complacent.

Q2c. With Aerospace Corporation's experience in independently assessing launch readiness, what capabilities do you expect to see in the Air Force organizations involved in the launch decision to be confident of a successful launch?

A2c. We expect our Air Force customer to hold us accountable for our mission assurance responsibilities and to demand the appropriate rigor and technical discipline in our independent assessments and recommendations.

Q2d. How do you evaluate the relationships between the Air Force and the contractors supplying the launchers when certifying readiness to launch? What represents an appropriate relationship between those two groups?

A2d. We rely on the contractors as the primary source of all data and the first line of defense in the mission assurance/readiness process. They provide assurance in their hardware, software, and procedures. It is our job to independently verify that all critical items (i.e., hardware, software, analyses, processes, and procedures) are technically acceptable. The appropriate relationship is one of cooperation and technical interchange with the independent technical party providing additional confidence through verification. The Air Force holds both the contractor and Aerospace accountable for independent mission assurance assessments.

Q3. In your testimony you state, "dissenting opinions are heard.. . ." What specifically are the forums for these dissenting opinions? How does your organization encourage dissent?

A3. For each launch we conduct a series of technical reviews at each level of management up to the corporation president. At each stage of these reviews, all disciplines and domain experts are represented and their findings and conclusions are presented. The launch vehicle programs rely on the domain experts in the Engineering and Technology Group to provide the technical basis for all positions. Each discipline presents all findings and must be in agreement on the readiness state. If a dissenting position is presented, it will be flagged and actions assigned to resolve. The existence of these issues is also tracked and the dispositions presented throughout the process. This process is also overseen by the Independent Readiness Review

Team that reports to the SMC Commander at the Flight Readiness Review in the form of a risk assessment.

Question submitted by Representative Nick Lampson

Q1. Admiral Bowman testified that, "Safety is the responsibility of everyone at every level in the organization," a sentiment echoed by Ms. Grubbe in her statement—but in day-to-day program activities, safety is not a primary metric for measuring performance. Safety usually becomes an issue only after it is clearly seen to be absent. What specific actions *does your organization take to maintain the focus on safety when the pressures to achieve organizational goals inevitably build?*

A1. We maintain an independent chain of mission assurance responsibility within our organization that flows up to our president. Although we are also responsible to the Air Force program director for his readiness assessment, our president reports to the SMC Commander who is above the program director and who ultimately certifies flight worthiness. It is this chain of command and the accountability expected at each level that assures our mission assurance focus is maintained.

Questions submitted by Representative Sheila Jackson Lee

Q1. How is safety training done in your organization? How is safety awareness maintained in your organization? Please describe the kinds of training materials you use.

A1. True safety training and certification is only required for those individuals at the launch site who support hazardous operations and are near the flight hardware. For industrial safety, our Safety and Security office is responsible for training in various procedures. They also have safety awareness circulars and other information media, such as the corporate website. For technical training we also have an educational arm of the corporation, The Aerospace Institute, that has a wide curriculum of space and national defense related courses. The Institute has classroom courses with appropriate text and other documentation for student's use. Our launch systems, systems engineering, and mission assurance functions are all contained in different modules within these courses. For those assigned specific mission assurance functions, we maintain a well-defined process and mentoring program that supports our technical staff.

ANSWERS TO POST-HEARING QUESTIONS

Responses by Deborah L. Grubbe, P.E., Corporate Director, Safety and Health, DuPont

Questions submitted by Representative Ralph M. Hall

Q1. How will we know that NASA has implemented the Columbia *Accident Investigation Board (CA1B) recommendations? What measures do you use in your organization to determine that your safety mechanisms are working?*

A1. We will know when the CAIB recommendations are in place when we see NASA leadership and management more focused on safety than on schedule. The diagnostic is as simple and as difficult as to watch what is done. In my firm we measure outcome metrics, e.g., the number of injuries and we also measure leading indicators, which is a measure of the general safety attitudes and procedures. With NASA I would start by looking at contractor and employee injury rates. If those start to improve, the indicator is there that management and leadership are taking safety seriously. There are literally hundreds of measures within an world class safety program.

Q2. The CAIB recommends a separation between the operational aspects of the Shuttle program and the organizations providing engineering and safety support. Based on your experience:

Q2a. Do you agree with this as a principle for managing your program?

A2a. Yes, my firm has independent authorities for both safety and for engineering.

Q2b. Where do you place the boundaries between these three program elements in your program and how do they interact?

A2b. All elements in my firm: manufacturing, safety and engineering interact at the local site, where the work is being done. In NASA terms, the work comes together at the center. We try to work with no boundaries at all times. We work to ensure alignment against the highest objective, which is to safely meet our customers' needs. If there is a point of disagreement, the management of the respective organizations are called in to help resolve the best approach.

Q2c. What training and experience do you require in your senior managers, and what incentives do you provide such managers?

A2c. Most managers have been "in those chairs" and know what it is like to see someone hurt. None of us who have been there ever want to see that again. The only true incentive for safety is, in the end, that everyone under my charge left today with all the parts they came with. There is a small monetary incentive at the corporate level, which may be as little as $500/year to someone making six figures. This money is really not much incentive, and is more recognition of job well done.

Q3. In both Shuttle accidents NASA failed to appreciate the threat to the vehicle from what seemed a minor problem—O-ring seals that did not seem to work well in cold weather and foam that sometimes struck the Orbiter's thermal protection system.

Q3a. How does your organization deal with similar "weak signals"?

A3a. My firm investigates anything that seems "out of the ordinary" or unexpected. We drive the answer to root cause, and put the fix into place as soon as practical. The important aspect of this work is to fix it before it becomes more serious.

Q3b. How does your organization evaluate problems to determine if they represent recurring failures that require changes in design or processes if they are to be dealt with? Who conducts those evaluations?

A3b. Our engineering and safety organizations, along with the collaboration of our manufacturing organization, looks to discern common cause and special cause variation. Both common cause and special cause variation provide data to direct the needed change.

Q3c. For recurring problems, does your organization have the capability to analyze the trend to determine if it could contribute to a low-probability, high-consequence accident?

A3c. Yes. Our organization, primarily our engineering organization, can do the analysis to quantify risk.

Q3d. How much certainty would your organization require to take action in a case where your relevant technical expert strongly believed a catastrophe could occur but did not have the engineering evaluations to confirm that judgment—and little or no time to conduct such evaluations?

A3d. My firm instructs its employees that if they do not feel safe, they are to stop their job and get someone to help them determine a better, safer way to do the work. An engineering evaluation does not have to do be done, someone just has to sense that "something is not right."

Questions submitted by Representative Bart Gordon

Q1. Does it matter in your organization whether a vehicle or product is deemed "operational" versus "experimental/developmental"? Do you have a different safety structure for operational activities versus those that are developmental in nature?

A1. The same safety standards apply whether the process or equipment is "operational" vs. "experimental."

Q2. One of the "cultural" issues raised in the CAIB report is the lack of respect for the safety organization demonstrated by the engineering and program offices at NASA. How does DuPont's safety organization avoid such marginalization?

A2. While there are many safety organizations in DuPont, every DuPont employee, and every DuPont contractor is accountable for safety. Safety is a line responsibility. Safety comes first. Period. No questions asked. No one in DuPont can ignore safety without consequences that could lead up to and include termination. If I discount safety, I can expect to hear about it from my boss, and he is not going to be happy! Likewise, with our corporate group. Since everyone is accountable for safety, it is never ignored. The safety organization can serve as the conscience on some occasions; however, you know safety is really working with the organization serves as its own conscience.

Question submitted by Representative Nick Lampson

Q1. Admiral Bowman testified that, "Safety is the responsibility of everyone at every level in the organization," a sentiment echoed by Ms. Grubbe in her statement—but in day-to-day program activities, safety is not a primary metric for measuring performance. Safety usually becomes an issue only after it is clearly seen to be absent. What specific actions *does your organization take to maintain the focus on safety when the pressures to achieve organizational goals inevitably build?*

A1. All major DuPont meetings start with a discussion of safety. Subjects include: statistics, what happened to me on the way home last night, weather safety, travel safety, etc. Others actions include the following: a monthly review of safety statistics at the global manufacturing meetings, reporting of lost time injuries within 24 hours to the CEO, and an aggressive off the job safety program where daily statistics are kept on lost time with off the job fatalities reported to the CEO within 24 hours. Safety statistics are shared daily with the whole organization, and we share improvement ideas frequently. We know that when we go through organizational changes, that safety can suffer, so we also redouble our efforts during difficult times.

Questions submitted by Representative Sheila Jackson Lee

Q1. How is safety training done in your organization? How is safety awareness maintained in your organization? Please describe the kinds of training materials you use.

A1. Safety training starts the first day of employment and continues monthly until one retires. Safety meeting attendance is mandatory. Safety awareness is maintained through items like: a global safety message that is sent out every working day at 2 a.m. EST, tool box meetings at the start of every shift, supervisor walk-through to support learning good safety techniques, etc. Training materials are items like: standards, videos, computer assisted tools, demonstrations, safety fairs, classes, safety meetings, written job procedures, pictures on how to best do the task, etc.

Q2. You mentioned in your written testimony that "any person can stop any job at any time if there is a perceived safety danger." What incentives do you use to encourage such action?

A2. People who stop a job, and people who offer an alert to an unsafe situation are highlighted at a safety meeting, or verbally recognized at a tool box meeting, or are sometimes even offered monetary recognition. The positive reinforcement is very affirming, and we continue to see more folks step forward and report unusual events. It is the driving home of the fixes on these unusual events that helps to keep people from getting hurt in the first place.

Appendix 2:

Additional Material for the Record

STATEMENT

OF

ADMIRAL H. G. RICKOVER, USN

DIRECTOR

NAVAL NUCLEAR PROPULSION PROGRAM

BEFORE THE

SUBCOMMITTEE ON ENERGY RESEARCH AND PRODUCTION

OF THE

COMMITTEE ON SCIENCE AND TECHNOLOGY

UNITED STATES HOUSE OF REPRESENTATIVES

MAY 24, 1979

NOTE: NOT FOR PUBLIC RELEASE UNTIL RELEASED BY THE COMMITTEE ON SCIENCE AND TECHNOLOGY

STATEMENT OF
ADMIRAL H. G. RICKOVER, USN
BEFORE THE
SUBCOMMITTEE ON ENERGY RESEARCH AND PRODUCTION OF THE
COMMITTEE ON SCIENCE AND TECHNOLOGY
U.S. HOUSE OF REPRESENTATIVES
MAY 24, 1979

YOU HAVE ASKED ME TO APPEAR BEFORE YOUR SUBCOMMITTEE IN ORDER TO DISCUSS MY OWN PERSPECTIVE ON NUCLEAR SAFETY AND TO DESCRIBE THE PHILOSOPHY AND APPROACH OF THE NAVAL REACTOR SAFETY PROGRAM. THE VIEWS I WILL EXPRESS ARE MY OWN BASED ON 60 YEARS OF GOVERNMENT SERVICE. THEY DO NOT NECESSARILY REFLECT THOSE OF MY SUPERIORS OF ANY GOVERNMENT AGENCY.

NAVAL REACTORS PROGRAM

I WILL BEGIN BY DESCRIBING THE EXTENT OF THE NAVAL REACTORS PROGRAM. TODAY 115 NUCLEAR POWERED SUBMARINES ARE IN OPERATION; 41 OF THESE ARE BALLISTIC MISSILE FIRING SUBMARINES AND 74 ARE ATTACK SUBMARINES. TWENTY-THREE ADDITIONAL ATTACK SUBMARINES AND SEVEN TRIDENT SUBMARINES ARE AUTHORIZED FOR CONSTRUCTION. WE ALSO HAVE ONE NUCLEAR POWERED DEEP SUBMERGENCE RESEARCH AND OCEAN ENGINEERING VEHICLE. THREE NUCLEAR POWERED AIRCRAFT CARRIERS ARE IN OPERATION, AND ONE MORE IS BEING BUILT. EIGHT NUCLEAR

POWERED CRUISERS ARE IN OPERATION, AND ONE MORE IS BEING BUILT. ALTOGETHER, 127 NUCLEAR POWERED SHIPS ARE IN OPERATION IN ADDITION, I AM RESPONSIBLE FOR THE SHIPPINGPORT ATOMIC POWER STATION. INCLUDING NUCLEAR SHIPS, THE NAVAL PROTOTYPE REACTORS, AND THE SHIPPINGPORT STATION, I AM RESPONSIBLE FOR THE OPERATION OF 153 REACTORS.

THERE ARE TWO DEPARTMENT OF ENERGY LABORATORIES DEVOTED TO THE SUPPORT OF THE NAVAL REACTORS PROGRAM: ONE IS THE BETTIS ATOMIC POWER LABORATORY IN PITTSBURGH, PENNSYLVANIA WHICH IS OPERATED BY WESTINGHOUSE; THE OTHER IS THE KNOLLS ATOMIC POWER LABORATORY LOCATED IN SCHENECTADY, NEW YORK, WHICH IS OPERATED BY THE GENERAL ELECTRIC COMPANY.

SINCE THE USS NAUTILUS FIRST PUT TO SEA IN 1955, NAVAL NUCLEAR POWERED SHIPS HAVE STEAMED OVER 40 MILLION MILES AND HAVE ACCUMULATED OVER 1800 REACTOR-YEARS OF OPERATION. WE HAVE PROCURED 508 NUCLEAR CORES, AND HAVE PERFORMED 166 REFUELINGS. SOME 300 LARGE BUSINESSES AND OVER 1000 SMALL BUSINESSES PRODUCE EQUIPMENT FOR THE NAVAL REACTORS PROGRAM.

ENVIRONMENTAL RECORD

IN THE TWENTY-SIX YEARS SINCE THE NAUTILUS LAND PROTOTYPE FIRST OPERATED THERE HAS NEVER BEEN AN ACCIDENT INVOLVING A NAVAL REACTOR, NOR HAS THERE BEEN ANY RELEASE OF RADIOACTIVITY

WHICH HAS HAD A SIGNIFICANT EFFECT ON THE ENVIRONMENT. FOR EXAMPLE, IN EACH OF THE LAST EIGHT YEARS, THE TOTAL GAMMA RADIOACTIVITY IN LIQUIDS, LESS TRITIUM, DISCHARGED WITHIN 12 MILES OF SHORE FROM ALL OUR NUCLEAR POWERED SHIPS, SUPPORTING TENDERS, NAVAL BASES AND NINE SHIPYARDS, WAS LESS THAN TWO THOUSANDTHS OF A CURIE. IF ONE PERSON WERE ABLE TO DRINK THE ENTIRE AMOUNT OF RADIOACTIVITY DISCHARGED INTO ANY HARBOR IN 1978, HE WOULD NOT EXCEED THE ANNUAL RADIATION EXPOSURE PERMITTED BY THE NUCLEAR REGULATORY COMMISSION FOR AN INDIVIDUAL WORKER.

EACH YEAR I ISSUE A REPORT WHICH DESCRIBES IN DETAIL THE RECORD OF DISCHARGES OF RADIOACTIVITY TO THE ENVIRONMENT FROM NAVAL SHIP OPERATIONS AND DESCRIBES OUR METHODS OF CONTROL AND ENVIRONMENTAL MONITORING. WITH YOUR PERMISSION I WILL PROVIDE THE SUBCOMMITTEE WITH A COPY OF THIS REPORT FOR 1978 FOR THE RECORD.

OCCUPATIONAL RADIATION EXPOSURE

FOR THE PAST TWO YEARS THERE HAS BEEN INCREASED PUBLIC AND CONGRESSIONAL INTEREST IN THE HEALTH EFFECTS DUE TO LOW LEVEL RADIATION. I AM NEITHER AN EXPERT ON RADIATION HEALTH EFFECTS NOR AM I RESPONSIBLE FOR SETTING THE NATIONAL OCCUPATIONAL EXPOSURE LIMITS. BUT I AM RESPONSIBLE FOR THE USE OF THESE

STANDARDS IN CONDUCTING RADIOACTIVE WORK IN THE NAVAL REACTORS PROGRAM. THUS I HAVE CONSIDERABLE EXPERIENCE IN WHAT IT TAKE TO PERFORM WORK WITH RADIOACTIVE MATERIAL IN A MANNER THAT PROTECTS THE WORKERS.

A SECOND DOCUMENT I WOULD LIKE TO PROVIDE FOR THE RECORD PROVIDES THE OCCUPATIONAL RADIATION EXPOSURE RECORD FOR CIVILIAN AND MILITARY PEOPLE INVOLVED IN NAVY NUCLEAR PROPULSION AND THEIR SUPPORT FACILITIES. ON PAGE 2 OF THIS REPORT, THERE IS A GRAPH WHICH SHOWS THE TOTAL OCCUPATIONAL RADIATION EXPOSURES TO PERSONNEL OPERATING SHIPS AND TO EMPLOYEES IN THE SHIPYARDS. IN 1978 THE TOTAL OPERATOR AND WORKER EXPOSURE WAS ABOUT ONE QUARTER THE AMOUNT IN THE PEAK YEAR 1966, EVEN THOUGH THE NUMBER OF NUCLEAR-POWERED SHIPS NEARLY DOUBLED.

AS IDENTIFIED IN THE DOCUMENT, SINCE 1967 NO CIVILIAN OR MILITARY PERSONNEL IN THE NAVY'S NUCLEAR PROPULSION PROGRAM HAVE EXCEEDED THE QUARTERLY FEDERAL LIMIT OF 3 REM OR AN ANNUAL RADIATION EXPOSURE LIMIT OF 5 REM. THE AVERAGE ANNUAL EXPOSURE OF SHIPYARD WORKERS IN 1978 WAS ONE QUARTER OF A REM. THE AVERAGE ANNUAL EXPOSURE OF SHIP OPERATORS IN 1978 WAS ONE TENTH OF A REM. THIS DOCUMENT ALSO OUTLINES MANY OF THE MEASURES IMPLEMENTED TO ACHIEVE THE RECORD OF OCCUPATIONAL RADIATION EXPOSURE WE HAVE ATTAINED.

I BELIEVE BOTH REPORTS WILL BE OF VALUE TO THE PURPOSE OF THIS HEARING, BECAUSE THEY CONVEY SOMETHING OF THE KIND OF CARE AND ATTENTION TO DETAIL WE HAVE TAKEN IN ORDER TO MAINTAIN A LEVEL OF ASSURANCE THAT BOTH THE PUBLIC AND THE PEOPLE IN THE PROGRAM ARE PROTECTED.

THREE MILE ISLAND INCIDENT

SINCE THE INCIDENT AT THE THREE MILE ISLAND SITE, I HAVE BEEN ASKED BY MANY PEOPLE TO COMMENT. THERE ARE SEVERAL REASONS WHY I HAVE NOT DONE THIS. FIRST, ALL THE FACTS ARE NOT IN, AND IT WOULD BE PRESUMPTUOUS ON MY PART TO MAKE JUDGMENTS ON SUCH A HIGHLY COMPLEX SUBJECT WHEN I DO NOT HAVE THE FACTS. SECOND, THERE ARE SIGNIFICANT DIFFERENCES BETWEEN THE DESIGN AND OPERATION OF NAVAL REACTORS AND PLANTS SUCH AS THE THREE MILE ISLAND PLANT. I WANT TO WEIGH ALL ASPECTS OF THE INCIDENT AND SEE IF THERE IS ANYTHING FROM IT I CAN LEARN AND INCORPORATE INTO THE NAVAL PROGRAM. THAT IS THE WAY I HAVE ALWAYS OPERATED.

Another important aspect is the legal issue involved. It is yet to be decided who will pay all the various costs for the incident. It would not be appropriate for a government employee such as myself to be issuing pronouncements on the incident when there may be litigation.

BASIC PRINCIPLES OF NAVAL REACTORS PROGRAM

There are, however, a number of facts which have been released by the Nuclear Regulatory Commission regarding Three Mile Island. These facts seem to me to reinforce many of the underlying basic principles of the Naval Reactors Program.

Over the years, many people have asked me how I run the Naval Reactors Program, so that they might find some benefit for their own work. I am always chagrined at the tendency of people to expect that I have a simple, easy gimmick that makes my program function. They are disappointed when they find out there is none. Any successful program functions as an integrated whole of many factors. Trying to select one aspect as the key one will not work. Each element depends on all the other elements.

I recall once several years ago an admiral, whose conventionally powered ships were suffering serious engineering

PROBLEMS, ASKED ME FOR A COPY OF ONE SPECIFIC PROCEDURE I USED TO IDENTIFY EQUIPMENT WHICH WAS NOT OPERATING PROPERLY. HE BELIEVED THAT WOULD SOLVE HIS PROBLEM, BUT IT DID NOT. THAT ADMIRAL DID NOT HAVE THE VAGUEST UNDERSTANDING OF THE PROBLEM OR HOW TO SOLVE IT, HE WAS MERELY SEARCHING FOR A SIMPLE ANSWER, A CHECK OFF LIST, THAT HE HOPED WOULD MAGICALLY SOLVE HIS PROBLEM.

I CANNOT OVEREMPHASIZE THE IMPORTANCE OF THIS THOUGHT IN YOUR CURRENT DELIBERATIONS. THE PROBLEMS YOU FACE CANNOT BE SOLVED BY SPECIFYING COMPLIANCE WITH ONE OR TWO SIMPLE PROCEDURES. REACTOR SAFETY REQUIRES ADHERENCE TO A TOTAL CONCEPT WHEREIN ALL ELEMENTS ARE RECOGNIZED AS IMPORTANT AND EACH IS CONSTANTLY REINFORCED.

TECHNICAL COMPETENCE

ONE OF THE ELEMENTS NEEDED IN SOLVING A COMPLEX TECHNICAL PROBLEM IS TO HAVE THE INDIVIDUALS WHO MAKE THE DECISIONS TRAINED IN THE TECHNOLOGY INVOLVED. A CONCEPT WIDELY ACCEPTED IN SOME CIRCLES IS THAT ALL YOU NEED IS TO GET A COLLEGE DEGREE IN MANAGEMENT AND THEN, REGARDLESS OF THE TECHNICAL SUBJECT, YOU CAN APPLY YOUR MANAGEMENT TECHNIQUES TO RUN ANY PROGRAM; INCLUDING THE PRESIDENCY, CONGRESS, OR THE VATICAN. THIS HAS BECOME A TENET OF OUR MODERN SOCIETY,

BUT IT IS AS VALID AS THE ONCE WIDELY HELD PRECEPT THAT THE WORLD IS FLAT. PROPERLY RUNNING A SOPHISTICATED TECHNICAL PROGRAM REQUIRES A FUNDAMENTAL UNDERSTANDING OF AND COMMITMENT TO THE TECHNICAL ASPECTS OF THE JOB AND A WILLINGNESS TO PAY INFINITE ATTENTION TO THE TECHNICAL DETAILS. THIS CAN ONLY BE DONE BY ONE WHO UNDERSTANDS THE DETAILS AND THEIR IMPLICATIONS. THE PHRASE "THE DEVIL IS IN THE DETAILS" IS ESPECIALLY TRUE FOR TECHNICAL WORK. IF YOU IGNORE THOSE DETAILS AND ATTEMPT TO RELY ON MANAGEMENT TECHNIQUES OR GIMMICKS YOU WILL SURELY END UP WITH A SYSTEM THAT IS UNMANAGEABLE, AND PROBLEMS WILL BE IMMENSELY MORE DIFFICULT TO SOLVE. AT NAVAL REACTORS, I TAKE INDIVIDUALS WHO ARE GOOD ENGINEERS AND MAKE THEM INTO MANAGERS. THEY DO NOT MANAGE BY GIMMICKS BUT RATHER BY KNOWLEDGE, LOGIC, COMMON SENSE, AND HARD WORK.

RESPONSIBILITY

ANOTHER ESSENTIAL ELEMENT IS THAT OF RESPONSIBILITY. IN THE BEGINNING OF THE NAVAL PROGRAM IT WAS APPARENT TO ME THAT DUE TO THE UNIQUENESS OF NUCLEAR POWER AND ITS POTENTIAL EFFECT ON PUBLIC SAFETY, A NEW CONCEPT OF TOTAL RESPONSIBILITY HAD TO BE ESTABLISHED BOTH WITHIN THE NAVY AND THE THEN ATOMIC ENERGY COMMISSION (AEC). IT WOULD NOT WORK IF ONE PERSON WAS RESPONSIBLE FOR NUCLEAR POWER PLANTS IN THE NAVY, AND A DIFFERENT PERSON RESPONSIBLE IN THE AEC. SIMILARLY, IT WOULD NOT WORK IF THERE WAS ONE PERSON IN THE THE AEC

RESPONSIBLE FOR THE NAVAL PROGRAM WITH A DIFFERENT PERSON RESPONSIBLE FOR THE AEC LABORATORIES DOING THE WORK FOR THE NAVAL REACTOR PROGRAM. IT WOULD NOT WORK IN THE NAVY IF FIVE OR SIX DIFFERENT ADMIRALS ALL HAD CHARGE OF DIFFERENT PIECES OF THE PROGRAM, AS IS OFTEN THE CASE IN OTHER AREAS. IT WOULD NOT WORK IF THERE WAS ONE PERSON RESPONSIBLE FOR RESEARCH AND DEVELOPMENT, SOMEONE ELSE RESPONSIBLE FOR CONSTRUCTION, AND ANOTHER RESPONSIBLE FOR TRAINING AND OPERATION, AND STILL ANOTHER FOR REPAIR WORK.

THIS KIND OF COMPARTMENTALIZATION OF RESPONSIBILITY IS TYPICAL IN GOVERNMENT WORK, BUT THE PRACTICE OF HAVING SHARED RESPONSIBLITY REALLY MEANS THAT NO ONE IS RESPONSIBLE. IT REMINDS ME OF THE FIGURE IN NEST'S CARTOON OF THE TWEED RING, WHERE ALL OF THE CHARACTERS STAND IN A CIRCLE, EACH ONE POINTING HIS THUMB AT HIS NEIGHBOR AS THE RESPONSIBLE PERSON. UNLESS YOU CAN POINT YOUR FINGER AT THE ONE PERSON WHO IS RESPONSIBLE WHEN SOMETHING GOES WRONG, THEN YOU HAVE NEVER HAD ANYONE REALLY RESPONSIBLE.

FOR THESE REASONS, I DID ALL I COULD TO GAIN SUPPORT FOR MY CONCEPT OF TOTAL RESPONSIBILITY. IT REQUIRED THAT A SINGLE POSITION BE ESTABLISHED TO HANDLE BOTH THE NAVY AND THE AEC PARTS OF THE JOB. I THINK IT MIGHT BE OF VALUE TO THIS SUBCOMMITTEE TO OUTLINE HOW THIS DESIGNATION OF RESPONSIBILITY WAS DERIVED FROM THE ATOMIC ENERGY ACT OF 1954, AND HOW IT

IS CARRIED OUT ALL THE WAY DOWN TO THE SHIPS, WHETHER IN CONSTRUCTION, OPERATION, OR OVERHAUL. I HAVE SUCH AN OUTLINE AND WITH YOUR PERMISSION I WOULD LIKE TO INCLUDE IT IN THE RECORD WITH MY STATEMENT.

I CAN ASSURE YOU THAT HAVING ONLY ONE INDIVIDUAL RESPONSIBLE FOR A TOTAL PROGRAM IS A UNIQUE CONCEPT WITHIN THE DEPARTMENT OF DEFENSE. I WANT TO EMPHASIZE THAT THROUGHOUT THIS ENTIRE PERIOD OF OVER THIRTY YEARS I HAVE HAD FULL SUPPORT FROM THE CONGRESS, MAINLY THROUGH THE FORMER JOINT COMMITTEE ON ATOMIC ENERGY AND THE ARMED SERVICES AND APPROPRIATIONS COMMITTEES, AND FROM THE ATOMIC ENERGY COMMISSION AND ITS SUCCESSORS, THE ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION AND NOW THE DEPARTMENT OF ENERGY. I HAVE NOT HAD SUCH CONSISTENT SUPPORT FROM THE NAVY OR THE DEPARTMENT OF DEFENSE.

FACING THE FACTS

ANOTHER PRINCIPLE FOR SUCCESSFUL APPLICATION OF A SOPHISTICATED TECHNOLOGY IS TO RESIST THE HUMAN INCLINATION TO HOPE THAT THINGS WILL WORK OUT, DESPITE EVIDENCE OR SUSPICIONS TO THE CONTRARY. THIS MAY SEEM OBVIOUS, BUT IT IS A HUMAN FACTOR YOU MUST BE CONSCIOUS OF AND ACTIVELY GUARD AGAINST. IT CAN AFFECT YOU IN SUBTLE WAYS, PARTICULARLY WHEN YOU HAVE SPENT A LOT OF TIME AND ENERGY ON A PROJECT AND FEEL PERSONALLY RESPONSIBLE FOR IT, AND THUS SOMEWHAT POSSESSIVE. IT IS A COMMON HUMAN PROBLEM AND IT IS NOT EASY

TO ADMIT WHAT YOU THOUGHT WAS CORRECT DID NOT TURN OUT THAT WAY.

IF CONDITIONS REQUIRE IT, YOU MUST FACE THE FACTS AND BRUTALLY MAKE NEEDED CHANGES DESPITE SIGNIFICANT COSTS AND SCHEDULE DELAYS. THERE HAVE BEEN A NUMBER OF TIMES DURING THE COURSE OF MY WORK THAT I HAVE MADE DECISIONS TO STOP WORK AND REDESIGN OR REBUILD EQUIPMENT TO PROVIDE THE NEEDED HIGH DEGREE OF ASSURANCE OR SATISFACTORY PERFORMANCE. THE PERSON IN CHARGE MUST PERSONALLY SET THE EXAMPLE IN THIS AREA AND REQUIRE HIS SUBORDINATES TO DO LIKEWISE.

I WILL NOW DISCUSS IN GREATER DETAIL THE UNDERLYING BASIC PRINCIPLES OF THE NAVAL REACTORS PROGRAM.

PRINCIPLES OF DESIGN AND ENGINEERING

FROM THE VERY BEGINNING OF THE NAVAL NUCLEAR PROPULSION PROGRAM I RECOGNIZED THAT THERE WERE A LARGE NUMBER OF ENGINEERING PROBLEMS IN PUTTING A NAVAL REACTOR INTO A SUBMARINE. SOME PROBLEMS WERE UNIQUE TO SUBMARINE APPLICATION, AND SOME TO THE GENERAL PROBLEM OF MAKING A REACTOR PLANT WORK. I REALIZED AT THE TIME THAT THE USE OF NUCLEAR POWER, AS WITH ANY NEW SOPHISTICATED TECHNOLOGY, WOULD REQUIRE THE INSTITUTION OF NOVEL REQUIREMENTS AND STANDARDS. I REALIZED THAT THESE REQUIREMENTS WOULD NECESSARILY BE DIFFICULT TO MEET, AND THE STANDARDS WOULD NEED TO BE MORE STRINGENT THAN

THOSE WHICH HAD BEEN USED IN POWER PLANTS UP TO THAT TIME. BUT WHEN YOU ARE AT THE FRONTIERS OF SCIENCE YOU MUST BE PREPARED TO ACCEPT THE DISCIPLINE THIS REQUIRES IN ORDER TO PROCEED. THE FACT THAT THE APPLICATION OF NUCLEAR POWER WAS ALMOST ENTIRELY AN ENGINEERING PROBLEM - NOT A PROBLEM OF NUCLEAR PHYSICS, AS NEARLY ALL OF THE "EXPERTS" THEN BELIEVED - WAS CLEAR TO ME. THE EMPHASIS I HAVE PLACED ON SOUND, CONSERVATIVE ENGINEERING HAS BEEN A MAJOR FACTOR IN THE PERFORMANCE OF OUR PLANTS.

I SHOULD POINT OUT THAT IN THE LATE 1940'S AND EARLY 1950'S, WHEN THE ORIGINAL NAVAL NUCLEAR PROPULSION PLANT DESIGN STUDIES BEGAN THERE WERE NO STANDARDS, DESIGN GUIDES, OR CODES AVAILABLE. THEY HAD TO BE DEVELOPED. DUE TO THE MILITARY APPLICATION, THESE DESIGN CRITERIA INCLUDED CONSIDERATIONS OF RELIABILITY, BATTLE DAMAGE, HIGH SHOCK AND THE CLOSE PROXIMITY OF THE CREW TO THE REACTOR PLANT. THE PROPULSION PLANT DESIGN HAD TO BE READILY MAINTAINABLE SO POSSIBLE EQUIPMENT FAILURES AT SEA COULD BE REPAIRED. THE FACT THAT MAJOR MAINTENANCE OPERATIONS WOULD BE INFREQUENT AND REFUELING POSSIBLY AS SELDOM AS ONCE IN A SHIP'S LIFETIME, REQUIRED THAT STANDARDS FOR MATERIALS AND SYSTEMS BE VERY RIGOROUS AND THAT ONLY PREMIUM PRODUCTS WHICH HAD A PROVEN PEDIGREE COULD BE CONSIDERED FOR USE. MY DESIGN OBJECTIVE IS AND HAS BEEN TO PROVIDE A WARSHIP THAT CAN BE RELIED UPON TO PERFORM ITS MISSION, AND RETURN.

CONSERVATISM OF DESIGN

I WILL EXPLAIN SOME OF THE ELEMENTS OF GOOD ENGINEERING AS I HAVE APPLIED THEM TO THE REACTOR PLANTS FOR WHICH I AM RESPONSIBLE. FIRST, IN ANY ENGINEERING ENDEAVOR, AND PARTICULARLY IN AN ADVANCED FIELD SUCH AS NUCLEAR POWER, CONSERVATISM IS NECESSARY, SO AS TO ALLOW FOR POSSIBLE UNKNOWN AND UNFORESEEN EFFECTS. THIS CONSERVATISM MUST BE BUILT INTO THE DESIGN FROM THE VERY BEGINNING. IF THE BASIC DESIGN IS NOT CONSERVATIVE, IT QUICKLY BECOMES IMPRACTICABLE TO PROVIDE THE NEEDED CONSERVATISM. IT THEN BECOMES NECESSARY TO ADD COMPLEXITIES TO THE SYSTEM IN AN ATTEMPT TO COMPENSATE FOR THE INADEQUACIES OF THE BASIC DESIGN. THESE COMPLEXITIES, IN TURN, SERVE TO REDUCE CONSERVATISM AND RELIABILITY.

I MUST MAKE IT CLEAR THAT THE MILITARY REQUIREMENTS WHICH MUST BE MET BY NAVAL PROPULSION REACTORS ARE FAR MORE EXACTING THAN THOSE WHICH CENTRAL STATION PLANTS MUST ENDURE. FOR EXAMPLE, THE SHOCK LOADINGS FOR WHICH NAVAL PLANTS ARE DESIGNED ARE FAR GREATER THAN THE EARTHQUAKE SHOCK LOADINGS FOR CIVILIAN PLANTS. IN ADDITION, NAVAL PLANTS MUST BE ABLE TO ACCOMODATE POWER TRANSIENTS MUCH MORE RAPIDLY THAN CIVILIAN PLANTS. EACH NAVAL VESSEL DEPENDS ENTIRELY ON ITS OWN REACTOR PLANT FOR THE CAPABILITY TO PERFORM ITS MISSION. FOR A SHIP THERE IS NO INTER-CONNECTED GRID TO PICK UP THE LOAD AND ALLOW THE SHIP TO CONTINUE FUNCTIONING. THE STRINGENT

REQUIREMENTS OF OPERATING A SHIP AT SEA ARE REFLECTED IN A CONSERVATIVE DESIGN WITH A LARGE OVERALL DESIGN MARGIN IN ALMOST EVERY ELEMENT OF THE PLANT.

SOME SPECIFIC EXAMPLES OF THE CONSERVATISM IN DESIGN WHICH I HAVE USED ARE:

- USE OF ORDINARY WATER OF HIGH PURITY AS THE REACTOR COOLANT. WATER HAS BEEN WIDELY USED IN INDUSTRIAL APPLICATIONS; ITS PROPERTIES ARE WELL-KNOWN, AND WHEN IRRADIATED, HAS SHORT-LIVED RADIOACTIVITY.

- USE OF CONSERVATIVE LIMITS FOR SYSTEMS AND EQUIPMENT. DESIGN IS BASED ON THE WORST CREDIBLE SET OF CIRCUMSTANCES, RATHER THAN RELYING ON A STATISTICAL APPROACH WHICH DEALS IN AVERAGE OR PROBABLE CONDITIONS.

- PROVISION IN THE DESIGN FOR REDUNDANCY SO THAT FAILURE OF ONE COMPONENT, OR ONE PORTION OF A SYSTEM, WILL NOT RESULT IN SHUTTING THE PLANT DOWN, OR IN DAMAGE TO THE REACTOR.

- DESIGN OF THE REACTOR PLANT TO ENABLE IT TO ACCOMODATE EXPECTED TRANSIENTS, WITHOUT THE NEED FOR IMMEDIATE OPERATOR ACTION. THIS MEANS THE PLANT IS INHERENTLY STABLE, AND HELPS THE OPERATOR WHEN THERE IS AN UNUSUAL TRANSIENT.

- SIMPLE SYSTEM DESIGN, SO THAT MINIMUM RELIANCE NEED BE PLACED ON AUTOMATIC CONTROL. RELIANCE IS PRIMARILY PLACED ON DIRECT OPERATOR CONTROL.

- SELECTION OF MATERIALS WITH WHICH THERE IS KNOWN EXPERIENCE FOR THE TYPE OF APPLICATION INTENDED, AND WHICH, INSOFAR AS PRACTICABLE, DO NOT REQUIRE SPECIAL CONTROLS FOR PROCUREMENT, FABRICATION, AND MAINTENANCE WHICH COULD LEAD TO PROBLEMS IF NOT PROPERLY ACCOMPLISHED.

- USE OF A LAND-BASED PROTOTYPE OF THE SAME DESIGN AS THE SHIPBOARD PLANT. THIS PROTOTYPE PLANT CAN BE TESTED AND SUBJECTED TO THE POTENTIAL TRANSIENTS A SHIPBOARD PLANT WILL EXPERIENCE, PRIOR TO OPERATION OF THE SHIPBOARD PLANT.

- USE OF EXTENSIVE ANALYSES, FULL SCALE MOCKUPS, AND TESTS TO CONFIRM THE DESIGN.

- STRICT CONTROL OF MANUFACTURE OF ALL EQUIPMENT, INCLUDING EXTENSIVE INSPECTIONS BY SPECIALLY TRAINED INSPECTORS DURING THE COURSE OF MANUFACTURE AND ON THE FINISHED EQUIPMENT. THIS MEANS THAT AT MANY POINTS DURING THE MANUFACTURE AN INDEPENDENT CHECK IS REQUIRED, WITH SIGNED CERTIFICATION THAT THE STEP HAS BEEN COMPLETED PROPERLY.

- Providing extensive detailed operating procedures and manuals, prepared and approved by technical people knowledgeable of the plant design. These manuals are constantly updated as we learn from the operations of the many other reactors. What we learn on one plant is incorporated into all our plants.

- Placing particular attention on designing, building and operating the plant so as to prevent accidents, and thus avoid undue reliance on the systems and procedures provided to cope with accidents which could occur.

- Use of frequent, thorough, and detailed audits of all aspects of the program by individuals who are specifically selected and trained.

- Use of formal documentation for design decisions, manufacturing procedures, inspection requirements, and inspection results.

- In addition to the detailed technical review and approval by my office, the safety aspects of operation of naval nuclear powered ships are independently reviewed by the Nuclear Regulatory Commission and the Advisory Committee on Reactor Safeguards.

APPROACH TO NEW REACTORS

THE KIND OF ENGINEERING APPROACH I HAVE JUST OUTLINED IS, IN MY OPINION, WHY THE NAVAL REACTORS PROGRAM HAS RESULTED IN SAFE, RELIABLE NUCLEAR POWER. TO THE CASUAL READER MUCH OF WHAT I HAVE SAID MAY APPEAR OBVIOUS. BUT I ASSURE YOU IT IS NOT WHEN YOU TRY TO CARRY OUT THESE CONCEPTS IN EVERYDAY WORK. I HAVE ENCOUNTERED MANY CASES WHERE THESE IDEAS ARE IGNORED OR NOT UNDERSTOOD. I HAVE, ON MANY OCCASIONS, REVIEWED PROPOSALS FOR SMALLER, LIGHTER, AND CHEAPER REACTORS. WHILE SUCH PROPOSALS HAVE COVERED A WIDE VARIETY OF REACTOR CONCEPTS, THEY HAVE BEEN COMPLETELY CONSISTENT IN ONE RESPECT; THEY HAVE ALL INVOLVED THE SACRIFICE OF SOUND, CONSERVATIVE ENGINEERING TO ACHIEVE A DESIGN THEORETICALLY HAVING BETTER PERFORMANCE. THEY EACH VIOLATED MOST, IF NOT ALL OF THE ENGINEERING PRINCIPLES I HAVE JUST DISCUSSED. THEY WOULD ALL HAVE BEEN, IN MY OPINION, UNSAFE AND UNSATISFACTORY FOR NAVAL WARSHIP APPLICATION. HOW OFTEN HAVE YOU KNOWN OF CASES WHERE IN THE FERVOR OF WINNING CONTRACTS, FIRMS WILL PROMISE ALL KINDS OF PERFORMANCE, ONLY TO BE FOUND INCAPABLE OF DELIVERING IT WHEN THEY TRY TO MAKE THE EQUIPMENT WORK. BY THIS, I DO NOT MEAN WE SHOULD NOT MAKE IMPROVEMENTS. WE HAVE. BUT AT ALL STAGES YOU MUST PROCEED IN ACCORDANCE WITH SOUND, CONSERVATIVE ENGINEERING PRACTICES IF YOU ARE TO PRODUCE SOMETHING THAT WILL WORK, VICE SOMETHING THAT IS JUST AN EXPENSIVE PIECE OF UNRELIABLE AND UNSAFE JUNK.

AS AN EXAMPLE, I HAVE OFTEN BEEN PRESSED TO REDUCE RADIATION SHIELDING TO MAKE NEW SHIPS SMALLER AND LIGHTER. HOWEVER, IF I REMOVED 100 TONS OF RADIATION SHIELDING FROM A TYPICAL SUBMARINE, THE SHIP WOULD BE ONLY TWO PERCENT LIGHTER. BUT THE RADIATION EXPOSURES TO SHIP PERSONNEL WOULD INCREASE TO TEN TIMES THE CURRENT LEVELS. I HAVE NOT AGREED TO REDUCING SHIELDING BECAUSE I BELIEVE RADIATION EXPOSURE TO PERSONNEL SHOULD BE AS LOW AS I CAN REASONABLY OBTAIN.

NAVAL NUCLEAR TRAINING

ANOTHER ELEMENT IN MY APPROACH TO SAFE OPERATION OF NAVAL REACTOR PLANTS INVOLVES THE SELECTION AND TRAINING OF THE OPERATORS. IN BRIEF, I CONSIDER THE TRAINING OF OFFICERS AND MEN TO BE AT LEAST AS IMPORTANT AS ANY OTHER ELEMENT OF THE NAVY NUCLEAR POWER PROGRAM. I CONSIDER IT OF THE GREATEST IMPORTANCE THAT THE MENTAL ABILITIES, QUALITIES OF JUDGMENT, AND LEVEL OF TRAINING, BE COMMENSURATE WITH THE RESPONSIBILITY INVOLVED IN OPERATING A NUCLEAR REACTOR. THE SELECTION OF PERSONNEL AND THEIR TRAINING IN THE NAVAL NUCLEAR POWER PROGRAM ARE CARRIED OUT WITH THESE CONSIDERATIONS IN MIND.

ACADEMIC ABILITY, PERSONAL CHARACTER AS DEMONSTRATED BY ANY ACTS REFLECTING UNRELIABILITY, AND HONEST DESIRE FOR THE NUCLEAR PROGRAM ARE ALL TAKEN INTO ACCOUNT IN SELECTION OF PERSONNEL. ONCE SELECTED FOR THE NAVAL NUCLEAR POWER PROGRAM, THE INDIVIDUAL IS CONTINUALLY SUBJECT TO REVIEW.

To accomplish these objectives, I require a one year training period prior to an operator going on board his first nuclear ship. The first six months of nuclear power training are spent at Nuclear Power School in Orlando, Florida, where the curriculum concentrates on the theoretical basis for shipboard systems. Upon graduation from Nuclear Power School the student reports to one of our land-based prototype plants where he learns to actually operate the propulsion plant. There the student must demonstrate that he can operate the plant under normal and casualty conditions, and is taught to operate in strict compliance with detailed operating and casualty procedures.

I established the Naval Nuclear Power Training Program on a base of rigid high standards. My staff at Naval Reactors approves the curriculum at Nuclear Power School and the qualification guides used to develop the prototype and shipboard operator qualificaiton programs. This ensures that the standards are not reduced by someone who does not understand the overall goals of the program, and that the individuals responsible for the design and construction of the reactor plant systems are involved in the training considerations on that system.

The methods we use in training involve lectures, seminars, homework assignments and both oral and written examinations.

WE ALSO REQUIRE OPERATORS TO BE ABLE TO DEMONSTRATE THEIR PRACTICAL KNOWLEDGE IN ORDER TO BECOME QUALIFIED AT THE LAND-BASED PROTOTYPE. THESE INDIVIDUALS MUST SUBSEQUENTLY QUALIFY ON BOARD SHIP. I AM NOT SATISFIED WITH BRINGING AN OPERATOR TO A QUALIFIED LEVEL ONCE, AND THEN FORGETTING ABOUT HIM. THEREFORE, WE CONTINUALLY REINFORCE THEORETICAL AND PRACTICAL TRAINING WITH A CONTINUING TRAINING PROGRAM. THIS INCLUDES FREQUENT PRACTICE IN PLANT EVOLUTIONS AND CASUALTY DRILLS.

THE EXAMINATIONS GIVEN MUST BE TOUGH, AND MUST BE APPROVED BY A COMPETENT PERSON IN AUTHORITY. INSTRUCTORS ARE TRAINED SO THAT THEY ARE CAPABLE OF CORRECTLY INSTRUCTING THE STUDENT. INSTRUCTORS, AS WELL AS STUDENTS, ARE MONITORED.

INSPECTIONS OF PERSONNEL IN THE FLEET ARE CONDUCTED BY MEMBERS OF MY STAFF, BOTH THOSE IN THE FIELD AND FROM HEADQUARTERS; BY THE FLEET NUCLEAR PROPULSION EXAMINING BOARDS ESTABLISHED BY THE CHIEF OF NAVAL OPERATIONS; AND BY NUCLEAR TRAINED PERSONNEL ON VARIOUS OTHER NAVAL STAFFS. I REVIEW THE RESULTS OF ALL THEIR INSPECTIONS.

I HAVE ESTABLISHED A FORMAL SYSTEM OF REPORTING PROPULSION PLANT PROBLEMS WHICH IDENTIFIES AREAS WHICH NEED IMPROVEMENT IN THE TRAINING PROGRAM. I ALSO REQUIRE THE COMMANDING OFFICER OF EACH NUCLEAR POWERED SHIP TO WRITE ME PERIODICALLY

CONCERNING PROPULSION PLANT PROBLEMS. THESE LETTERS CONTAIN A SUMMARY OF THE TRAINING HE HAS CONDUCTED AND ALLOW ME TO PERSONALLY CHECK THE ADEQUACY.

THESE ARE JUST THE MAIN ELEMENTS OF THE TRAINING EFFORTS IN MY PROGRAM. BECAUSE TRAINING IS SO IMPORTANT, I WANT TO PROVIDE A MUCH MORE DETAILED DESCRIPTION OF WHAT WE DO FOR YOUR RECORD. I KNOW YOU DO NOT HAVE TIME FOR ME TO READ THIS DESCRIPTION NOW, BUT I STRONGLY RECOMMEND THAT ALL THE COMMITTEE MEMBERS READ IT BECAUSE IT MAY BE OF VALUE IN YOUR REVIEW.

MISTAKES MUST BE TAKEN INTO ACCOUNT

WHAT I HAVE PRESENTED AT THIS POINT REPRESENTS THE MAIN SUBSTANCE OF MY STATEMENT. IN IT I HAVE OUTLINED WHAT I DO IN RUNNING THE NAVAL REACTORS PROGRAM. EVEN WHEN THESE MEASURES ARE CARRIED OUT IT IS IMPORTANT TO RECOGNIZE THAT MISTAKES WILL BE MADE, BECAUSE WE ARE DEALING WITH MACHINES AND THEY CANNOT BE MADE PERFECT. THE HUMAN BODY IS GOD'S FINEST CREATION AND YET WE GET SICK. IF WE CANNOT HAVE PERFECT HUMAN BEINGS THEN WHY SHOULD WE EXPECT, PHILOSOPHICALLY, THAT MACHINES DESIGNED BY HUMAN BEINGS WILL BE MORE PERFECT THAN THEIR CREATORS? THAT IS WHAT MANY UNTHINKING PEOPLE DEMAND EVEN THOUGH THE LORD HIMSELF DID NOT REACH THIS HEIGHT. I BELIEVE IF YOU FOLLOW THE PRACTICES OF CONSERVATIVE

ENGINEERING AND PERSONNEL TRAINING I HAVE OUTLINED AND IF YOU CARRY THEM OUT WITH STEADFAST COMMITMENT, NUCLEAR POWER CAN BE SAFELY USED, EVEN TAKING INTO ACCOUNT MISTAKES THAT WILL INEVITABLY OCCUR. THAT IS THE BASIS ON WHICH I HAVE CONDUCTED ALL MY WORK IN THIS FIELD AND I BELIEVE IT TRUE JUST AS STRONGLY TODAY AS I EVER HAVE.

DECISION ON NUCLEAR POWER

AS WELL AS ANYONE IN THIS ROOM, I RECOGNIZE THAT NUCLEAR POWER IS A VERY DIFFICULT SUBJECT FOR ANYONE TO DEAL WITH. IT INVOLVES ENERGY - A VITAL ELEMENT IN OUR NATION'S FUTURE. IT INVOLVES INDIVIDUALS' CONCERNS FOR THEMSELVES AND THEIR FAMILIES, AND IT IS A HIGHLY TECHNICAL, SOPHISTICATED TECHNOLOGY. ULTIMATELY, THE DECISION AS TO WHETHER WE WILL HAVE NUCLEAR POWER IS A POLITICAL ONE - IN THE TRUE SENSE OF THE WORD - THAT IS, ONE MADE BY THE PEOPLE THROUGH THEIR ELECTED REPRESENTATIVES. IT IS VITAL THAT THE DECISION BE MADE ON THE BASIS OF FACT, NOT RHETORIC, NOT CONJECTURE OR HOPE, OR AS A RESULT OF THE WIDESPREAD TENDENCY TO SENSATIONALIZE THE CURRENT TOPIC AND IGNORE THE REAL LIMITS OR RISKS OF THE ALTERNATIVE.

I AM NOT AN EXPERT OR EVEN PARTICULARLY KNOWLEDGEABLE IN THE AREAS OF ENVIRONMENTAL EFFECTS OF OTHER FORMS OF

POWER GENERATION. HOWEVER, I AM AWARE THAT A GOOD MANY KNOWLEDGEABLE PEOPLE CONCLUDE THAT THE TOTAL RISK INVOLVED IN THE USE OF NUCLEAR POWER IS NO GREATER THAN IS INVOLVED IN THE USE OF ANY ALTERNATE SOURCE WHICH CAN BE TAPPED IN THE NEXT 50 YEARS.

I ALSO REMEMBER THE OPTIMISTIC PROJECTIONS MADE FOR NUCLEAR POWER WHEN IT WAS FIRST BEING DEVELOPED. THESE SPRANG FROM HOPE AND FROM IGNORANCE OF THE REAL ENGINEERING PROBLEMS THAT WOULD BE ENCOUNTERED IN USING NUCLEAR POWER. THERE IS NO REASON TO BELIEVE THAT CURRENT PROJECTIONS FOR ALTERNATE MEANS OF PROVIDING LARGE AMOUNTS OF POWER ARE ANY MORE PRECISE. ANY LARGE SCALE GENERATION OF POWER INVOLVES MAJOR ENGINEERING DIFFICULTIES AND POTENTIAL ENVIRONMENTAL IMPACTS.

THE JOB OF THIS COMMITTEE AND THE CONGRESS IN THE DAYS AHEAD WILL NOT BE EASY. I HOPE AND PRAY YOU WILL FIND THE STRENGTH AND WISDOM TO MAKE THE RIGHT DECISIONS. I ALSO HOPE THAT MY TESTIMONTY WILL IN SOME WAY CONTRIBUTE TO YOUR DIFFICULT DELIBERATIONS.

NAVAL NUCLEAR PROPULSION OPERATOR TRAINING PROGRAM

I WILL NOW DISCUSS IN GREATER DEPTH THE PERSONNEL ASPECTS OF THE NAVAL NUCLEAR PROPULSION PROGRAM. I WILL DESCRIBE WHAT IS INVOLVED IN THE SELECTION, TRAINING, QUALIFICATION, AND REQUALIFICATION OF THE OPERATORS; AND I WILL DESCRIBE THE METHODS AND PROCEDURES USED TO ENSURE THAT POLICIES AND DIRECTIVES OF THE NUCLEAR PROGRAM ARE CARRIED OUT. AS I HAVE PREVIOUSLY STATED, ALL OF THESE ELEMENTS MUST MESH FOR THE SYSTEM TO WORK. YOU CANNOT SEPARATE OUT AND USE THE PIECES WHICH YOU LIKE, AND DISCARD THOSE WHICH ARE "TOO HARD".

BY THE SAME TOKEN, IT IS IMPOSSIBLE TO SEPARATE TRAINING FROM THE TECHNICAL SIDE OF THE NUCLEAR PROGRAM. WITHIN THE NAVAL REACTORS HEADQUARTERS ORGANIZATION, ALL OF THE ENGINEERS ARE VERY MUCH AWARE OF THE IMPACT OF ENGINEERING DECISIONS ON THE OPERATING PERSONNEL AND OF THE REQUIREMENTS FOR TRAINING ON NEW EQUIPMENT OR PROCEDURES. THIS IS ALSO TRUE FOR THE ENGINEERS WHO WORK AT OUR TWO LABORATORIES. ALSO, MANY OF THE MORE EXPERIENCED ENGINEERS IN NAVAL REACTORS HEADQUARTERS ASSIST IN CERTAIN PHASES OF THE PERSONNEL SELECTION PROCESS FOR OPERATORS AND ARE DIRECTLY INVOLVED IN THE TRAINING CONDUCTED AT NAVAL REACTORS.

YOU SHOULD ALSO NOTE THE LONGEVITY OF EXPERIENCE AT NAVAL REACTORS, NOT JUST AS IT RELATES TO ME BUT AS IT IS MANIFESTED IN THE LARGE MAJORITY OF PEOPLE IN MY HEADQUARTERS ORGANIZATION. APPROXIMATELY ONE-FOURTH OF MY HEADQUARTERS ENGINEERS HAVE BEEN IN THE NAVAL REACTORS PROGRAM FOR MORE THAN TWENTY YEARS. THIS EXPERIENCE AND STABILITY IS IMPORTANT NOT JUST IN TRAINING BUT IN ALL ASPECTS OF THE PROGRAM.

WHEN THE NUCLEAR PROPULSION PROGRAM STARTED, MORE THAN THIRTY YEARS AGO, I REALIZED IT WAS NECESSARY TO HAVE EXCELLENCE IN OPERATING PERSONNEL. IN VIEW OF THE POSSIBLE SERIOUS CONSEQUENCES OF A REACTOR ACCIDENT I CONSIDERED IT OF UTMOST IMPORTANCE THAT THE OPERATION OF NUCLEAR POWERED SHIPS BE ENTRUSTED ONLY TO THOSE WHOSE MENTAL ABILITIES, QUALITIES OF JUDGMENT AND DEGREEE OF TRAINING WERE COMMENSURATE WITH THE PUBLIC RESPONSIBILITY INVOLVED. THE PERSONNEL SELECTION AND TRAINING PROCEDURES FOR THE NAVAL NUCLEAR PROPULSION PROGRAM WERE DEVELOPED WITH THESE CONSIDERATIONS IN MIND. THEY HAVE EVOLVED WITH EXPERIENCE OVER THE LAST TWENTY-FIVE YEARS AND ARE STILL CHANGING. I DO NOT SAY THAT USE OF THESE METHODS IS THE ONLY WAY, BUT THIS IS THE WAY IT HAS BEEN FOUND TO WORK IN THE NAVAL PROGRAM, AND I DO NOT KNOW OF A BETTER WAY TO DO IT. IF I DID, I WOULD USE IT.

EARLIER IN MY STATEMENT I DISCUSSED THE GENERAL PRINCIPLES I HAVE USED TO FORM THE BASIS OF THE NAVAL NUCLEAR PROPULSION

PROGRAM. I WILL STATE THOSE WHICH RELATE TO PERSONNEL AND TRAINING, AND THEN ATTEMPT TO SHOW HOW THESE ARE ACHIEVED.

(1) CAREFUL SELECTION OF PERSONNEL.

(2) EXTENSIVE INITIAL TRAINING FOR PERSONNEL (PRIOR TO SHIPBOARD ASSIGNMENT), INCLUDING THE USE OF ACTUAL OPERATING PROTOTYPE PLANTS.

(3) A THOROUGH QUALIFICATION AND REQUALIFICATION PROGRAM FOR ALL PERSONNEL.

(4) CONSTANT REINFORCEMENT OF PRINCIPLES AND PROCEDURES BY A FORMAL CONTINUING TRAINING PROGRAM FOR ALL OPERATORS. THIS PROGRAM STRIVES TO CONTINUALLY UPGRADE THE KNOWLEDGE AND UNDERSTANDING OF OPERATORS AT ALL QUALIFICATION LEVELS.

(5) FREQUENT PRACTICE OF CASUALTY DRILLS AND PLANT EVOLUTIONS IN ALL OPERATING SHIPS AND PROTOTYPES.

(6) CONTINUING REVIEW OF PERSONNEL PERFORMANCE AND REMOVAL FROM THE PROGRAM OF THOSE WHO DO NOT MEET STANDARDS.

(7) FREQUENT INSPECTIONS OF PLANTS AND PLANT OPERATIONS BY PERSONNEL ASSIGNED TO THE PLANT AND BY HIGHER AUTHORITY WITH SYSTEMATIC FOLLOW UP ON DEFICIENCIES.

(8) A FEEDBACK SYSTEM IN WHICH DESIGN, MATERIAL, PERSONNEL AND PROCEDURAL PROBLEMS ARE BROUGHT PROMPTLY TO MY PERSONAL ATTENTION TOGETHER WITH THE CORRECTIVE ACTION REQUIRED IN EACH CASE.

(9) A COMMON BASE OF HIGH STANDARDS OF PERSONNEL PERFORMANCE IN ALL AREAS INCLUDING STRICT COMPLIANCE WITH DETAILED OPERATING AND CASUALTY PROCEDURES.

SELECTION OF PERSONNEL

THE RESPONSIBILITIES INVOLVED IN OPERATING NAVAL NUCLEAR POWERED SHIPS AND THE REQUIREMENTS OF THE NUCLEAR PLANTS THEMSELVES MAKE IT ESSENTIAL THAT INDIVIDUALS IN THE PROGRAM HAVE A HIGH DEGREE OF INTELLIGENCE AND CAPACITY TO LEARN. EARLY IN THE PROGRAM I RECOGNIZED THAT NORMAL PROCEDURES OF PERSONNEL SELECTION AND ASSIGNMFNT USED BY THE NAVY COULD NOT BE COUNTED ON TO PROVIDE THIS PROGRAM WITH THE PROPER TYPE OF INDIVIDUAL. IN ORDER TO SELECT CANDIDATES OF THE NECESSARY INTELLECTUAL CAPACITY AND MOTIVATION, A NUMBER OF SPECIAL MEASURES HAD TO BE TAKEN. HOWEVER, I COULD NOT JUST FOLLOW TYPICAL CIVILIAN PROCEDURES. RECOGNITION HAD TO BE GIVEN TO THE FACT THAT I WAS DEALING WITH A BODY OF MILITARY PEOPLE. THIS MEANT WE WOULD BE FACED WITH THE INEVITABLE HIGH TURNOVER RATE, THE PROBLEMS TYPICAL OF YOUNG, INEXPERIENCED ENLISTED MEN, AND THE ANTIQUATED NAVY TRAINING METHODS.

REQUIREMENTS FOR OFFICERS

OFFICERS FOR ASSIGNMENT TO THE ENGINEERING CREWS OF THE FIRST NUCLEAR-POWERED SHIPS WERE, BY NECESSITY, DRAWN FROM

THOSE HAVING HAD PREVIOUS SHIPBOARD EXPERIENCE. WHILE I KNEW THIS WAS NOT THE BEST WAY, I HAD NO CHOICE. AS THE NUMBER OF NUCLEAR-POWERED SHIPS GREW, THE SOURCE OF SEA-EXPERIENCED OFFICERS BECAME INSUFFICIENT TO SUPPORT THE NEEDS. THEREFORE, BEGINNING IN 1960, A NUMBER OF TOP RANKING STUDENTS GRADUATING FROM THE NAVAL ACADEMY, NROTC COLLEGES, AND FROM THE NAVY'S OFFICER CANDIDATE SCHOOL WERE SELECTED TO ENTER NUCLEAR POWER TRAINING FOLLOWING GRADUATION. IN 1969 THE NUCLEAR POWER OFFICER CANDIDATE (NUPOC) PROGRAM WAS ADDED THROUGH WHICH TOP GRADUATES OF ALL COLLEGES ARE GIVEN THE OPPORTUNITY TO APPLY FOR NUCLEAR POWER TRAINING. TODAY, THESE PROGRAMS WHICH TAKE OFFICERS DIRECTLY FROM THE NAVAL ACADEMY OR CIVILIAN COLLEGES ACCOUNT FOR MORE THAN 95% OF THE OFFICERS ENTERING THE NUCLEAR TRAINING PROGRAM. TO DATE, SOME 7,000 OFFICERS HAVE BEEN TRAINED IN THE NUCLEAR POWER PROGRAM.

OFFICERS WHO APPLY FOR NUCLEAR TRAINING MUST BE COLLEGE GRADUATES MEETING MINIMUM REQUIREMENTS FOR COURSES IN MATHEMATICS AND SCIENCE. THE COLLEGE RECORDS ARE SCREENED TO DETERMINE SCHOLASTIC APTITUDE, AND PERFORMANCE. FOR THOSE OFFICERS WITH SEA EXPERIENCE, NAVAL RECORDS ARE ALSO REVIEWED TO DETERMINE EFFECTIVENESS AS NAVAL OFFICERS, EXPERIENCE LEVEL (PARTICULARLY IN ENGINEERING), AND THEIR COMMANDING OFFICER'S EVALUATION OF THEM AS CANDIDATES FOR THE NUCLEAR PROGRAM. THIS SCREENING IS PERFORMED BY THE BUREAU OF NAVAL

PERSONNEL WITH THE ADVICE AND ASSISTANCE OF NAVAL REACTORS PERSONNEL.

IN ORDER TO FURTHER ENSURE THAT ONLY OFFICERS WITH THE NECESSARY POTENTIAL AND MOTIVATION ARE SELECTED FOR THE NAVAL NUCLEAR PROPULSION PROGRAM, THE CANDIDATES ARE EACH CALLED TO WASHINGTON AND INTERVIEWED BY SEVERAL SENIOR MEMBERS OF MY STAFF AND FINALLY BY ME. IN ADDITION TO PROVIDING INFORMATION OVER AND ABOVE THAT AVAILABLE IN AN OFFICER'S SERVICE RECORD ON HIS INTELLIGENCE AND ABILITY, THESE INTERVIEWS ARE USEFUL IN DETERMINING THE WILLINGNESS OF THE OFFICER TO UNDERTAKE THE DIFFICULT TRAINING PROGRAM FOR NUCLEAR PROPULSION ASSIGNMENT AND HIS INTEREST IN PROFESSIONAL ADVANCEMENT AS EVIDENCED BY HIS WORK AND STUDY HABITS.

THIS PROCESS OF INTERVIEWING HAS BEEN CRITICIZED FOR YEARS BY MANY SENIOR NAVAL OFFICERS. I AM CONTINUALLY ASKED TO ABOLISH THIS PROCEDURE WITH THE SUGGESTION THAT ALL I NEED TO DO IS SET DOWN SOME STANDARDS ON ACADEMIC REQUIREMENTS AND ALL THOSE WHO MEET THEM CAN BE ORDERED INTO TRAINING. IF THEY PASS THE RIGOROUS TRAINING PROGRAM THEN THEY ARE ACCEPTABLE. THERE ARE A NUMBER OF REASONS WHY I DO NOT AGREE WITH THIS SUGGESTION. FIRST OF ALL, THE INTERVIEWS ARE ABLE TO DETECT AN INDIVIDUAL WHO MAY HAVE GOOD SCHOOL GRADES BUT WHO IS REALLY INCAPABLE OF PASSING THE COURSE.

THIS HAS BEEN PARTICULARLY TRUE OVER THE PAST FIFTEEN YEARS WHEN COLLEGE GRADES HAVE GENERALLY LOST MEANING. IT IS A WASTE OF MONEY AND EFFORT TO ALLOW A PERSON TO ENTER TRAINING WHO THEN FAILS, PARTICULARLY IF YOU CAN PREDICT THE FAILURE AHEAD OF TIME. THE OTHER REASON I INSIST ON THE INTERVIEWS IS MORE BASIC. SOME CANDIDATES MAY HAVE PERFECTLY FINE GRADES AND COULD UNDOUBTEDLY PASS THE ACADEMIC PORTION OF THE COURSE. HOWEVER, THEY MAY HAVE ABSOLUTELY NO CAPABILITY TO BE PUT IN CHARGE OF THE OPERATION OF A REACTOR PLANT. IF I CAN NOT BE CONVINCED IN MY OWN MIND THAT THAT OFFICER CAN BE TAUGHT TO CARRY OUT HIS DUTIES RESPONSIBLY WITH REGARD TO THE SAFE OPERATION OF THE REACTOR PLANT AT SEA UNDER TRYING CONDITIONS, THEN I CANNOT AND WILL NOT ACCEPT HIM. TO ME THIS IS A VERY IMPORTANT PART OF THE PROGRAM.

REQUIREMENTS FOR ENLISTED PERSONNEL

AS IN THE CASE OF OFFICERS, IN THE EARLY YEARS OF THE NUCLEAR PROGRAM ENLISTED CANDIDATES CAME FROM THE FLEET AND HAD SHIPBOARD ENGINEERING EXPERIENCE. THOSE WHO APPLIED WERE INTERVIEWED AND SCREENED BY THEIR COMMANDING OFFICERS BEFORE BEING RECOMMENDED AS CANDIDATES. ELIGIBILITY CRITERIA WERE ESTABLISHED BY THE CHIEF OF NAVAL PERSONNEL WITH THE ADVICE AND ASSISTANCE OF NAVAL REACTORS. ASSIGNMENT TO THE NUCLEAR PROGRAM WAS MADE BY THE BUREAU OF NAVAL PERSONNEL

FROM AMONG THOSE RECOMMENDED.

THE MANNING REQUIREMENTS FOR THE EXPANDING NUCLEAR SUBMARINE PROGRAM AND THE NUCLEAR SURFACE SHIP PROGRAM REQUIRED A NEW SOURCE OF PEOPLE FOR TRAINING. IN 1957 DIRECT INPUT OF ENLISTED MEN FOR NUCLEAR PROPULSION TRAINING WAS PROVIDED BY A PROGRAM OF RECRUITING PROMISING YOUNG HIGH SCHOOL GRADUATES INTO THE NAVY, SPECIFICALLY FOR ULTIMATE DUTY IN NUCLEAR SHIP ENGINEERING DEPARTMENTS. TODAY THIS PROGRAM IS THE PRIMARY SOURCE OF ENLISTED PERSONNEL FOR NUCLEAR POWER TRAINING. APPROXIMATELY 40,000 ENLISTED OPERATORS HAVE COMPLETED THE NAVAL NUCLEAR PROPULSION TRAINING PROGRAM TO DATE.

THE SUPERVISION, OPERATION, AND MAINTENANCE OF NAVAL NUCLEAR PROPULSION PLANTS REQUIRE A HIGH LEVEL OF COMPETENCE, RELIABILITY, AND EXPERTISE. FOR THESE REASONS HIGH SELECTION CRITERIA WERE ESTABLISHED EARLY IN THE PROGRAM. LATER, AS THE NUMBER OF PERSONNEL IN THE PROGRAM INCREASED, WE EXPERIENCED HIGHER ATTRITION IN THE TRAINING CYCLE. TO REDUCE THIS ATTRITION, THE EDUCATIONAL SELECTION CRITERIA WERE MADE MORE RESTRICTIVE.

TODAY, ALL ENLISTED APPLICANTS FOR NUCLEAR TRAINING MUST BE HIGH SCHOOL GRADUATES WHO HAVE COMPLETED ONE YEAR OF ALGEBRA IN HIGH SCHOOL OR COLLEGE, AND HAVE ACHIEVED AT

LEAST A "C" OR EQUIVALENT GRADE IN THAT COURSE. ADDITIONALLY, ALL CANDIDATES MUST DEMONSTRATE HIGH ACADEMIC ABILITY IN THE AREAS OF MATH AND SCIENCE AS MEASURED BY THE ARMED SERVICES VOCATIONAL APTITUDE BATTERY TESTS AND THE NUCLEAR FIELD QUALIFICATION TEST. THESE ARE ADMINISTERED BY THE NAVY RECRUITING COMMAND PRIOR TO AN APPLICANT'S SELECTION FOR NUCLEAR TRAINING. THESE TESTS GIVE AN INDICAITON OF THE APPLICANT'S ABILITY TO HANDLE THE STUDY OF MATHEMATICS AND PHYSICS; SUBJECTS WHICH FORM THE BASIS OF THE NUCLEAR POWER TRAINING CURRICULUM.

SELECTION OF NUCLEAR PERSONNEL, OFFICER OR ENLISTED, MUST NECESSARILY REQUIRE AN IN-DEPTH REVIEW OF A CANDIDATE'S CHARACTER IN ADDITION TO HIS ACADEMIC CAPABILITY. FOR THIS REASON, ANY PERSON WHO HAS BEEN CONVICTED OF, OR WHO IS IDENTIFIED AS HAVING COMMITTED, A SERIOUS OFFENSE WILL NOT BE ACCEPTED. A SINGLE MINOR OFFENSE INVOLVING MORAL TURPITUDE OR WHICH EVIDENCES UNRELIABILITY MAY BE CONSIDERED DISQUALIFYING. FREQUENT TRAFFIC VIOLATIONS OR ACCIDENTS THAT INDICATE UNRELIABILITY, RECKLESSNESS OF CHARACTER, OR BASIC DISREGARD FOR AUTHORITY MAY ALSO BE CAUSE FOR DENYING ENTRY INTO THE NUCLEAR PROGRAM.

ANY INDIVIDUAL WHO HAS BEEN CONVICTED OF, OR IS IDENTIFIED AS, HAVING ILLEGALLY, WRONGFULLY, OR OTHERWISE IMPROPERLY

USED, POSSESSED OR SOLD MARIJUANA OR OTHER DRUGS WILL BE DENIED ENTRY INTO OR CONTINUATION IN THE NUCLEAR PROGRAM. ANYONE SHOWING SIGNS OF BEING OR BECOMING ADDICTED TO ALCOHOL IS ALSO EXCLUDED FROM ENTRY INTO THE PROGRAM. WAIVERS FOR ENTRY INTO THE NUCLEAR POWER PROGRAM MAY BE GRANTED IN THE CASE OF PRE-SERVICE USE OF MARIJUANA WHERE IT CAN BE ESTABLISHED THAT THE USAGE WAS OF AN INFREQUENT EXPERIMENTAL NATURE AND FURTHER USE HAS BEEN STOPPED. A WAIVER OF THIS TYPE MAY ONLY BE GRANTED BY THE COMMANDER, NAVY RECRUITING COMMAND WITH THE CONCURRENCE OF THE CHIEF OF NAVAL PERSONNEL. PERSONNEL ON MY STAFF AT NAVAL REACTORS REVIEW AND CONCUR IN EACH CASE IN WHICH A WAIVER IS GRANTED.

IT SHOULD BE NOTED HERE THAT THESE WAIVERS MAY BE GRANTED <u>ONLY</u> FOR PRE-SERVICE USE OF MARIJUANA. THE ILLEGAL USE OF ANY DRUG, INCLUDING MARIJUANA, AFTER ENTRY INTO THE SERVICE IS NOT TOLERATED. THIS COMES TO LIGHT FROM TIME TO TIME AND ALL INDIVIDUALS INVOLVED ARE IMMEDIATELY REMOVED FROM FURTHER DUTY INVOLVING NUCLEAR POWER. NO MATTER HOW EXEMPLARY THEIR SUBSEQUENT PERFORMANCE MAY BE, THEY ARE NOT ALLOWED TO RETURN AS NUCLEAR PROPULSION PLANT OPERATORS.

NUCLEAR TRAINED PERSONNEL ARE SUBJECT TO A CONTINUING RELIABILITY SCREENING PROCESS FROM THE MOMENT THEY ARE APPROVED FOR ENTRY INTO THE PROGRAM. ALL DISCIPLINARY INFRACTIONS, WHETHER CIVILIAN OR MILITARY IN NATURE, ARE REVIEWED TO DETERMINE AN INDIVIDUAL'S ELIGIBILITY FOR

CONTINUATION IN THE NUCLEAR POWER PROGRAM. REVIEWS OF RECORDS ARE CONDUCTED IN ORDER TO IDENTIFY DISQUALIFYING PROFESSIONAL PERFORMANCE, AS WELL AS DISQUALIFYING MEDICAL OR PSYCHOLOGICAL FACTORS.

PRE-NUCLEAR PROGRAM TRAINING

INITIAL NAVAL TRAINING OF ENLISTED PERSONNEL SELECTED FOR NUCLEAR TRAINING IS CONDUCTED AT SEVERAL TRAINING SITES THROUGHOUT THE COUNTRY. DURING BASIC RECRUIT TRAINING, THE CANDIDATE IS SCREENED AND CLASSIFIED INTO ONE OF THE PROGRAM RATINGS (MACHINIST'S MATE, ELECTRICIAN'S MATE, INTERIOR COMMUNICATIONS, OR ELECTRONICS TECHNICIAN) ACCORDING TO HIS CAPABILITIES AND THE NEEDS OF THE PROGRAM. THE TRAINEE THEN ATTENDS APPROPRIATE NAVY CLASS "A" SCHOOL TRAINING, WHICH VARIES IN LENGTH FROM TWO TO FIVE MONTHS. THE CURRICULA ARE BASIC TO THE RATINGS AND ARE NOT SPECIALIZED FOR NUCLEAR POWER. THESE CLASS "A" SCHOOLS ARE OPERATED BY THE CHIEF OF NAVAL EDUCATION AND TRAINING, AND ARE NOT CONTROLLED BY NAVAL REACTORS. NUCLEAR PROGRAM TRAINEES COMPLETING CLASS "A" SCHOOL TRAINING WILL NORMALLY BE ORDERED DIRECTLY TO NUCLEAR POWER SCHOOL AT ORLANDO, FLORIDA.

IT SHOULD BE NOTED HERE, THAT UNTIL A NUCLEAR PROGRAM ENLISTEE COMMENCES SPECIALIZED NUCLEAR POWER TRAINING AT

ORLANDO, HE HAS ATTENDED GENERAL NAVY SCHOOLS AND TRAINED IN HIS RATING ALONGSIDE HIS CONVENTIONAL ENGINEERING COUNTERPART. IF HE IS UNABLE TO SATISFY THE DEMANDING ACADEMIC REQUIREMENTS IN THE NUCLEAR SCHOOLS, THEN HE IS IMMEDIATELY AVAILABLE TO BE ASSIGNED TO A CONVENTIONAL ENGINEERING BILLET OF HIS RATING. THOSE MEN WHO LEAVE THE NUCLEAR PROGRAM FOR ACADEMIC FAILURE ARE THEREFORE ABLE TO CONTINUE THEIR NAVAL SERVICE AND MAKE A VALUABLE CONTRIBUTION TO THE AT-SEA MANNING OF THE CONVENTIONAL NAVY IN TECHNICAL FIELDS. IN ADDITION, NEARLY ALL OF THE NAVY'S REQUIREMENTS FOR NUCLEAR TRAINED PERSONNEL ARE FOR SEA DUTY. THEREFORE, IT IS IMPORTANT THAT NUCLEAR TRAINED PERSONNEL ARE ABLE TO FILL GENERAL NAVY RATING BILLETS BECAUSE THE FEW NUCLEAR SHORE BILLETS WOULD NOT PROVIDE REASONABLE SEA-SHORE ROTAION. THIS WOULD ADVERSELY AFFECT THE RETENTION OF OUR NUCLEAR TRAINED PERSONNEL.

OBJECTIVES AND PHASES OF NAVAL NUCLEAR PROPULSION TRAINING

THE OBJECTIVE OF THE NAVAL NUCLEAR PROPULSION TRAINING PROGRAM IS TO PREPARE OFFICERS AND ENLISTED ENGINEERING PERSONNEL TO DISCHARGE THEIR RESPONSIBILITY FOR SAFE AND EFFECTIVE OPERATION OF PROPULSION PLANTS OF NUCLEAR-POWERED SHIPS. THIS IS ACCOMPLISHED BY TEACHING THEM: (1) THE PRINCIPLES OF SCIENCE AND ENGINEERING WHICH ARE FUNDAMENTAL TO THE DESIGN, CONSTRUCTION, AND OPERATION OF NAVAL NUCLEAR PROPULSION PLANTS; AND (2) THE DETAILS AND PRACTICAL KNOWLEDGE

REQUIRED TO OPERATE AND MAINTAIN THESE PLANTS.

THE PROGRAMS TO TRAIN PERSONNEL FOR ENGINEERING DUTY ABOARD NAVAL NUCLEAR-POWERED SHIPS ARE CENTERED AROUND FOUR MAJOR PHASES - FORMAL ACADEMIC INSTRUCTION, OPERATIONAL TRAINING AT ONE OF THE DEPARTMENT OF ENERGY LAND-BASED NAVAL REACTOR PROTOTYPES, TRAINING AND QUALIFICATION AS A WATCHSTANDER ABOARD AN OPERATING NAVAL NUCLEAR-POWERED SHIP, AND CONTINUING SHIPBOARD TRAINING. EACH OF THESE FOUR PHASES IS ESSENTIAL IN THE SATISFACTORY TRAINING OF AN OPERATOR AND PROVIDING ASSURANCE THAT ONLY THOSE WHO ARE MENTALLY AND EMOTIONALLY CAPABLE, AND WHO HAVE DEMONSTRATED ABILITY AS A COMPETENT NUCLEAR PROPULSION PLANT OPERATOR ARE ASSIGNED DUTY ABOARD NUCLEAR-POWERED SHIPS.

FORMAL ACADEMIC INSTRUCTION

THE NUCLEAR PROPULSION TRAINING PROGRAM BEGAN IN 1951 WITH THE ENGINEERING OFFICERS AND CREW OF THE NAUTILUS. THE INITIAL THEORETICAL TRAINING WAS GIVEN AT THE ATOMIC ENERGY COMMISSION'S NAVAL REACTORS LABORATORY IN PITTSBURGH, PENNSYLVANIA. WHEN CONSTRUCTION OF THE NAUTILUS PROTOTYPE IN IDAHO WAS SUFFICIENTLY ADVANCED, THE TRAINEES WERE TRANSFERRED TO THE PROTOTYPE WHERE THEY CONTINUED BOTH THEORETICAL AND OPERATIONAL TRAINING. UPON REPORTING TO THE NAUTILUS AT THE BUILDING YARD, DETAILED SHIPBOARD TRAINING WAS CONDUCTED THROUGHOUT THE CONSTRUCTION, TEST, AND TRIAL PERIOD, UNDER

SUPERVISION OF NAVAL REACTORS AND CONTRACTOR PERSONNEL. A SIMILAR PROGRAM WAS COMMENCED IN 1953 FOR THE SEAWOLF ENGINEERING OFFICERS AND MEN AT THE ATOMIC ENERGY COMMISSION NAVAL REACTORS LABORATORY AND PROTOTYPE SITE IN WEST MILTON, NEW YORK. AS THE NUMBER OF NUCLEAR-POWERED SHIPS AUTHORIZED FOR CONSTRUCTION INCREASED, IT WAS RECOGNIZED THAT A PROGRAM CAPABLE OF TRAINING LARGE NUMBERS OF OFFICERS AND ENLISTED MEN SHOULD BE ESTABLISHED. THE NAVAL NUCLEAR POWER SCHOOL WAS ESTABLISHED AT NEW LONDON, CONNECTICUT IN JANUARY, 1956 AND GRADUATED ITS FIRST CLASS OF NUCLEAR SUBMARINE OFFICERS IN JUNE, 1956. THIS SCHOOL WAS SUBSEQUENTLY RELOCATED AT BAINBRIDGE, MARYLAND.

ACADEMIC TRAINING FOR SURFACE SHIP OFFICERS WAS CONTINUED AT THE IDAHO PROTOTYPE SITE UNTIL 1959 WHEN A SECOND NAVAL NUCLEAR POWER SCHOOL WAS ESTABLISHED AT MARE ISLAND, CALIFORNIA, FOR BOTH SURFACE AND SUBMARINE PERSONNEL. FROM 1959 UNTIL 1976 ALL FORMAL ACADEMIC TRAINING FOR OFFICERS AND ENLISTED PERSONNEL IN THE NAVAL NUCLEAR PROGRAM WAS CARRIED OUT AT ONE OF THESE TWO NAVAL NUCLEAR POWER SCHOOLS. IN 1976, THE SCHOOL AT BAINBRIDGE, MARYLAND WAS MOVED TO ORLANDO, FLORIDA AND IN 1977 THE SCHOOL AT MARE ISLAND, CALIFORNIA MERGED WITH THE NUCLEAR POWER SCHOOL, ORLANDO, WHERE ALL FORMAL ACADEMIC TRAINING IS PRESENTLY CONDUCTED.

PURPOSE OF NUCLEAR POWER SCHOOL

THE PURPOSE OF NAVAL NUCLEAR POWER SCHOOL, ORLANDO IS TO TEACH OFFICER AND ENLISTED STUDENTS THOSE PRINCIPLES OF SCIENCE AND ENGINEERING FUNDAMENTALS NECESSARY FOR THE UNDERSTANDING OF THE OPERATION OF NAVAL NUCLEAR PROPULSION PLANTS, AND TO PREPARE THEM FOR FUTURE ASSIGNMENT TO PROTOTYPE TRAINING AND EVENTUAL RESPONSIBILITIES RELATING TO THE SAFE AND EFFECTIVE OPERATION OF PROPULSION PLANTS OF NUCLEAR POWERED SHIPS.

IN PURSUIT OF THIS PURPOSE WE SET HIGH STANDARDS AND WE STICK TO THEM. WE STRESS THAT THE OPERATOR MUST BE TRAINED IN BASIC PRINCIPLES, SO THAT HE KNOWS NOT ONLY WHAT HE IS DOING, BUT WHY. WE TEACH BASIC THEORY, PRINCIPLES OF THE BASIC COMPONENTS AND SYSTEMS, AND APPLICATION OF THESE SYSTEMS AND THEORY TO WATCHSTATION DUTIES. THE STUDENTS ARE TESTED WITH FREQUENT AND DEMANDING EXAMINATIONS TO BE SURE THEIR KNOWLEDGE CAN BE APPLIED, NOT JUST THEIR MEMORY EXERCISED. WE MOTIVATE THEM TO PERFORM, AND DO NOT ALLOW THEM TO PROCEED AT THEIR OWN PACE, IF IT IS TOO SLOW. CLASSROOM INSTRUCTION TAKES PRIORITY OVER EVERYTHING ELSE AT NUCLEAR POWER SCHOOL.

NUCLEAR POWER SCHOOL ORGANIZATION

NUCLEAR POWER SCHOOL IS COMPRISED OF FOUR DEPARTMENTS UNDER A COMMANDING OFFICER AND EXECUTIVE OFFICER. A PRE-SCHOOL DEPARTMENT, ENLISTED DEPARTMENT, OFFICER DEPARTMENT, AND

ADMINISTRATIVE DEPARTMENT MAKE UP THIS ORGANIZATION.

THE COMMANDING OFFICER IS RESPONSIBLE FOR THE ACADEMIC PROGRAM. HE CERTIFIES THAT INSTRUCTORS ARE TECHNICALLY PREPARED TO TEACH, APPROVES THE EXAMINATIONS, MONITORS THE PERFORMANCE OF THE INSTRUCTORS AND RECOMMENDS STUDENT DISENROLLMENTS.

DEPARTMENT HEADS ARE RESPONSIBLE FOR THE COURSE CONTENT SPECIFIED IN APPROVED TOPICAL GUIDES. THEY ARE RESPONSIBLE FOR INSTRUCTOR TRAINING, REVIEW OF PROPOSED EXAMINATIONS, AND MONITORING THE PERFORMANCE OF INSTRUCTORS IN THEIR RESPECTIVE DEPARTMENTS.

THE COMMANDING OFFICER OF NUCLEAR POWER SCHOOL HAS ALREADY SERVED AS COMMANDING OFFICER OF A NUCLEAR POWERED SHIP. THE EXECUTIVE OFFICER IS NUCLEAR TRAINED AND HAS SERVED AS THE EXECUTIVE OFFICER OF A SHIP. THE ACADEMIC DEPARTMENT HEADS HAVE ALL SERVED AS ENGINEER OFFICERS OF NUCLEAR POWERED SHIPS.

THE INSTRUCTORS AT NUCLEAR POWER SCHOOL COME FROM TWO SOURCES:

(1) DIRECT INPUT OFFICERS RECRUITED SPECIFICALLY TO SERVE AS INSTRUCTORS. THEY ARE SELECTED BY NAVAL REACTORS IN THE SAME MANNER AS OFFICER STUDENTS BUT MUST MEET HIGHER ACADEMIC CRITERIA IN THEIR EDUCATIONAL FIELD. AFTER A SIX WEEK NAVY INDOCTRINATION COURSE AT NEWPORT, RHODE ISLAND, THEY REPORT TO NUCLEAR POWER SCHOOL TO TEACH FOR THEIR FOUR YEAR TOUR OF DUTY IN THE NAVY. MANY OF THESE OFFICERS HAVE ADVANCED DEGREES

IN THEIR ACADEMIC SPECIALTY.

(2) OFFICER AND ENLISTED INSTRUCTORS WHO HAVE ALREADY COMPLETED A TOUR OF SEA DUTY ON A NUCLEAR POWERED SHIP. TYPICALLY THESE SEA RETURNEE INSTRUCTORS HAVE GRADUATED IN THE TOP FIFTY PERCENT OF THEIR NUCLEAR POWER SCHOOL AND PROTOTYPE CLASSES. THEY ALSO HAVE AN EXCELLENT FLEET PERFORMANCE RECORD. OFFICER INSTRUCTORS SO ASSIGNED HAVE ALREADY QUALIFIED TO SERVE AS ENGINEER OFFICER OF A NUCLEAR POWERED SHIP.

PRE-SCHOOL DEPARTMENT

THE PURPOSE OF PRE-NUCLEAR POWER SCHOOL IS TO BRING ALL ENLISTED STUDENTS TO A COMMON ACCEPTABLE LEVEL IN MATHEMATICS AND PHYSICS; TO PREPARE STUDENTS MEDICALLY AND ADMINISTRATIVELY FOR ENROLLMENT; AND TO TEACH STUDENTS HOW TO STUDY. THE LENGTH OF PRE-SCHOOL IS EITHER SIX OR THREE WEEKS DEPENDING UPON THE INDICATED ACADEMIC ABILITY OF THE STUDENT BASED ON THE NUCLEAR FIELD QUALIFICATION TEST SCORE AND PREVIOUS NAVY SCHOOL PERFORMANCE. THE PRE-SCHOOL CURRICULUM IS NOT PART OF THE NUCLEAR POWER SCHOOL CURRICULUM FOR TRAINING THE INDIVIDUAL TO BE A NUCLEAR PROPULSION PLANT OPERATOR. PRE-SCHOOL GIVES STUDENTS WITH WEAK HIGH SCHOOL ACADEMIC BACKGROUNDS A BETTER OPPORTUNITY TO PASS THE RIGOROUS NUCLEAR POWER SCHOOL COURSE; IT ALSO FACILITATES ASSIGNMENT OF PERSONNEL SO THAT LESS TIME IS WASTED BETWEEN COMPLETION OF NAVY RATING SCHOOL AND COMMENCEMENT OF NUCLEAR POWER SCHOOL.

ENLISTED DEPARTMENT

THE ENLISTED DEPARTMENT IS MADE UP OF SEVEN ACADEMIC DIVISIONS EACH HEADED BY A DIVISION DIRECTOR. THE DIVISION DIRECTOR IS RESPONSIBLE FOR THE SUBJECT CONTENT OF THE COURSE IN ACCORDANCE WITH APPROVED TOPICAL GUIDES; FOR TRAINING HIS INSTRUCTORS; AND FOR PREPARING ALL OF HIS EXAMINATIONS. THE ACADEMIC DIVISIONS CONCENTRATE ON THE QUALITY OF THEIR TEACHING, THE QUALITY OF THEIR GROUP EXTRA INSTRUCTION AND INDIVIDUAL TUTORING WHICH IS GIVEN TO THE WEAKER STUDENTS.

THE ENLISTED DEPARTMENT IS ALSO ORGANIZED MILITARILY TO PROVIDE ADVISORS WHO COUNSEL THE STUDENTS.

OFFICER DEPARTMENT

THE OFFICER DEPARTMENT IS ORGANIZED IN A SIMILAR MANNER TO THE ENLISTED DEPARTMENT, WITH THE EXCEPTION THAT THE INSTRUCTORS ALSO FILL A MILITARY ROLE AS ADVISORS AND COUNSELORS.

CIVILIAN SUPPORT, BETTIS TECHNICAL CONSULTANTS

TWO EXPERIENCED CIVILIAN SCIENTISTS FROM THE BETTIS ATOMIC POWER LABORATORY ARE IN RESIDENCE AT NUCLEAR POWER SCHOOL AS TECHNICAL CONSULTANTS.

THE ROLE OF THE BETTIS TECHNICAL CONSULTANTS IS TO ACT AS A TECHNICAL ADVISOR TO NUCLEAR POWER SCHOOL STAFF, MAINTAIN LIAISON BETWEEN NUCLEAR POWER SCHOOL AND THE BETTIS ATOMIC POWER LABORATORY, AND MONITOR NUCLEAR POWER SCHOOL EFFECTIVENESS. THEY ALSO ASSIST THE INSTRUCTORS IN PREPARING AND PRESENTING THE COURSE MATERIAL.

NUCLEAR POWER SCHOOL CURRICULUM

THE NUCLEAR POWER SCHOOL CURRICULUM IS PREPARED UNDER MY DIRECTION BY THE NAVAL REACTORS STAFF IN WASHINGTON. THE ASSISTANCE OF THE NAVAL REACTORS LABORATORIES IS UTILIZED IN DEVELOPING THE CURRICULUM. THE COURSE AT NUCLEAR POWER SCHOOL LASTS SIX MONTHS AND CONSISTS OF APPROXIMATELY 700 HOURS OF CLASSROOM INSTRUCTION.

THE OFFICER STUDENT CURRICULUM INCLUDES MATHEMATICS, PHYSICS, HEAT TRANSFER AND FLUID FLOW, ELECTRICAL ENGINEERING, REACTOR DYNAMICS, CHEMISTRY, ASPECTS OF REACTOR PLANT OPERATIONS, MATERIALS, RADIOLOGICAL FUNDAMENTALS, CORE CHARACTERISTICS AND REACTOR PLANT SYSTEMS, WHICH IS AN OVERVIEW OF ALL MECHANICAL AND

ELECTRICAL SYSTEMS. OFFICERS RECEIVE INSTRUCTION UP TO AND INCLUDING THE GRADUATE LEVEL.

THE ENLISTED CURRICULUM INCLUDES REACTOR PLANT SYSTEMS, MATHEMATICS, PHYSICS, HEAT TRANSFER AND FLUID FLOW, REACTOR PRINCIPLES, CHEMISTRY, RADIOLOGICAL FUNDAMENTALS, MATERIALS, SPECIALIZED IN-RATE INSTRUCTION ON PLANT SYSTEMS AND REACTOR PLANT OPERATIONS. ENLISTED PERSONNEL RECEIVE INSTRUCTION AT THE UNDERGRADUATE COLLEGE LEVEL.

THE CURRICULUM IS CAREFULLY ORGANIZED TO PROVIDE THE PRINCIPLES OF SCIENCE AND ENGINEERING NECESSARY FOR UNDERSTANDING THE OPERATION OF NAVAL NUCLEAR PROPULSION PLANTS. EACH SUBJECT SERVES AS A BUILDING BLOCK SUPPORTING THE STUDENTS FURTHER TRAINING. FOR EXAMPLE: THE REACTOR PLANT SYSTEMS SUBJECT MATTER SUPPORTS THE HEAT TRANSFER AND FLUID FLOW SUBJECT. MATHEMATICS SUPPORTS ALL SUBJECTS. PHYSICS SUPPORTS REACTOR PRINCIPLES, CHEMISTRY, AND RADIOLOGICAL FUNDAMENTALS SUBJECTS. ALL COURSES USE SHIPBOARD EXAMPLES WHEN EXPLAINING CONCEPTS. FOR EXAMPLE, IN MATHEMATICS THE INSTRUCTOR AVOIDS USING ABSTRACT EQUATIONS AND USES THE FORMULAS FROM THE SUBJECTS THAT WILL BE STUDIED AT THE SCHOOL.

CONTROL OF THE CURRICULUM STARTS WITH TOPICAL GUIDES. THERE IS A TOPICAL GUIDE FOR EVERY SUBJECT TAUGHT AT NUCLEAR POWER SCHOOL. THE TOPICAL GUIDE IS ORIGINATED BY THE NUCLEAR POWER SCHOOL STAFF, REVIEWED BY THE BETTIS LABORATORY, AND

APPROVED BY NAVAL REACTORS. THE PURPOSE OF A TOPICAL GUIDE IS TO REGULATE THE SUBJECT BY SPECIFYING WHAT MUST BE COVERED, THE ORDER IN WHICH THE TOPICS MUST BE COVERED, THE TIME ALLOTTED FOR EACH TOPIC, AND WHEN EXAMINATIONS MUST BE GIVEN. LESSON PLANS ARE DEVELOPED FROM THESE TOPICAL GUIDES FOR USE IN TEACHING A CLASS. IN ADDITION, STUDENT LEARNING OBJECTIVES ARE DEVELOPED FROM THE TOPICAL GUIDES. THESE OBJECTIVES TELL THE STUDENTS WHAT THEY SHOULD BE GETTING OUT OF THE COURSE.

THE BASIS FOR TEXTBOOK AND OTHER DOCUMENT SELECTION IS THAT THEY WILL DIRECTLY SUPPORT NUCLEAR POWER SUBJECTS, AS WELL AS INCLUDE ADDITIONAL INFORMATION TO CHALLENGE EVEN THE BEST STUDENT. MANUALS ARE PREPARED FOR NUCLEAR POWER SCHOOL FOR USE BY THE SCHOOL, THE PROTOTYPES, AND THE SHIPS IN THE FLEET. THESE MANUALS ARE PREPARED BY THE BETTIS OR KAPL LABORATORIES AND APPROVED BY NAVAL REACTORS PRIOR TO ISSUE. USE OF COMMERCIAL TEXTS FOR SOME SUBJECTS ARE APPROVED BY NAVAL REACTORS. REACTOR PLANT MANUALS AND OTHER TECHNICAL MANUALS ARE USED FOR INSTRUCTOR REFERENCE. BOOKS CONTAINING PRACTICE PROBLEMS FOR EACH SUBJECT ARE PREPARED BY THE NUCLEAR POWER SCHOOL AND GIVEN TO STUDENTS TO BE USED THROUGHOUT THE COURSE.

INSTRUCTOR QUALITY CONTROL

THE INITIAL TRAINING OF A NEW INSTRUCTOR TAKES ABOUT THREE MONTHS. DURING THIS INITIAL TRAINING THE NEW INSTRUCTOR IS FIRS

REQUIRED TO TAKE THE SUBJECT HE WILL TEACH. HE WILL GIVE PRACTICE LECTURES AND BECOME FAMILIAR WITH RELATED NUCLEAR POWER SCHOOL SUBJECTS. THE NEW INSTRUCTOR MUST PASS ORAL BOARDS ON THE TECHNICAL CONTENT OF THE COURSE, AND PRESENT A CERTIFICATION LECTURE FOR THE DIVISION DIRECTOR, THE DEPARTMENT HEAD, AND THE COMMANDING OFFICER. HE MUST ALSO PASS AN ORAL CERTIFICATION BOARD BY THE DIVISION DIRECTOR, THE DEPARTMENT HEAD, AND THE COMMANDING OFFICER. AFTER QUALIFICATION, THE TRAINING CONTINUES SO THAT THE INSTRUCTOR WILL REMAIN CURRENT AND KNOWLEDGEABLE. AN ANNUAL WRITTEN EXAMINATION IS ADMINISTERED TO ALL INSTRUCTORS TO DETERMINE ANY WEAK AREAS. THE INSTRUCTOR'S CLASSROOM PRESENTATION IS AUDITED AT LEAST TWICE DURING EACH PERIOD HE TEACHES A SUBJECT. THE COMMANDING OFFICER, THE EXECUTIVE OFFICER AND THE DEPARTMENT HEADS ARE REQUIRED TO AUDIT ONE INSTRUCTOR EACH WEEK. ALSO BETTIS TECHNICAL CONSULTANTS RANDOMLY MONITOR THE INSTRUCTORS. EVALUATION REPORTS ARE FILLED OUT BY THE AUDITORS AND DISCUSSED WITH THE INSTRUCTOR. THESE REPORTS ARE FORWARDED UP THE CHAIN OF COMMAND AND FILED IN THE INSTRUCTOR TRAINING FOLDER AFTER ANY NECESSARY CORRECTIVE ACTION HAS BEEN TAKEN.

EXAMINATIONS

BOTH OFFICER AND ENLISTED STUDENTS ARE REQUIRED TO PASS A FOUR HOUR WRITTEN COMPREHENSIVE EXAMINATION PRIOR TO GRADUATION. IN ADDITION, THERE ARE WEEKLY QUIZES AND A TWO HOUR EXAMINATION ABOUT EVERY TEN DAYS. NO MULTIPLE CHOICE OR TRUE AND FALSE QUESTIONS ARE USED ON ANY EXAMINATIONS AT NUCLEAR POWER SCHOOL.

QUESTIONS INVOLVE SINGLE AND MULTIPLE CONCEPTS WHICH REQUIRE ESSAY ANSWERS, DEFINITIONS, STATEMENTS OF FACTS, OR CALCULATIONS. THE PHILOSOPHY OF QUESTIONING IS TO EXAMINE THE STUDENT IN BASIC THEORY AND THE APPLICATION OF THIS THEORY TO THE PRINCIPLES OF OPERATION OF THE BASIC PLANT COMPONENTS AND SYSTEMS.

CAREFUL QUALITY CONTROL IS EXERCISED IN THE PREPARATION AND ADMINISTRATION OF EXAMINATIONS. EACH EXAMINATION IS WRITTEN AND REVIEWED BY TWO MEMBERS OF THE ACADEMIC DIVISION. A TRIAL EXAMINATION IS GIVEN TO ANOTHER MEMBER AS A CHECK ON ANY PROBLEMS WHICH MAY ARISE WITH THE QUESTIONS ON THE EXAMINATION OR THE TIME ALLOTTED FOR THE EXAMINATION. THE EXAMINATION IS THEN REVIEWED AND APPROVED BY THE ACADEMIC DIVISION DIRECTOR, THE DEPARTMENT HEAD, THE BETTIS TECHNICAL CONSULTANT AND FINALLY THE COMMANDING OFFICER. EXAMINATIONS ARE REVIEWED TO INSURE THAT THEY MEET THE OBJECTIVES OF THE SUBJECT TOPICAL GUIDES, ARE TECHNICALLY ACCURATE, AND HAVE ACCEPTABLE ANSWERS ON THE ANSWER KEYS. THEY MUST MEET THE STANDARDS OF DIFFICULTY FOR THE INDIVIDUAL QUESTIONS AND FOR THE TOTAL EXAMINATION.

AFTER THE EXAMINATION HAS BEEN GIVEN AND GRADED IT IS REVIEWED BY THE INSTRUCTOR WITH ALL OF HIS STUDENTS DURING THE NEXT CLASS PERIOD. AT THIS TIME THE INSTRUCTOR DISCUSSES THE CONCEPTS THAT GAVE THE STUDENTS THE MOST DIFFICULTY. IF A STUDENT FAILS AN EXAMINATION, THE INSTRUCTOR INTERVIEWS HIM TO ANALYZE HIS PERFORMANCE ON THE EXAMINATION, SO THAT CORRECTIVE ACTION CAN BE EFFECTIVE.

STUDENT CONTROL

STUDENT PERFORMANCE IS CONTINOUSLY MONITORED. INSTRUCTORS MONITOR STUDENT PERFORMANCE BY GRADING DAILY HOMEWORK, GIVING FREQUENT QUIZZES AND A 2 TO 3 HOUR EXAMINATION ABOUT EVERY 10 DAYS. ADVISORS MONITOR THE STUDENTS PERFORMANCE BY INTERVIEWING STUDENTS WHO HAVE ACADEMIC PROBLEMS WEEKLY, AND EVERY STUDENT AT LEAST EVERY TWO WEEKS. THE ADVISOR REVIEWS RECORDS OF STUDENT STUDY HOURS FOR CORRELATION WITH THE STUDENT'S ACADEMIC PERFORMANCE. IF THE STUDENT'S GRADES ARE BELOW AVERAGE HE IS REQUIRED TO SIGN IN WHENEVER HE STUDIES AT THE SCHOOL SO THAT HIS STUDY HOURS CAN BE CHECKED. THE ADVISOR ALSO MONITORS THE STUDENT BY ATTENDING THE LECTURES AND OBSERVING THE STUDENT'S PARTICIPATION. IN ADDITION, THE ADVISOR MEETS WITH ALL HIS STUDENT'S INSTRUCTORS AT LEAST EVERY TWO WEEKS TO DISCUSS INDIVIDUAL OR GROUP STUDENT PERFORMANCE. THE CLASS DIRECTOR MEETS WEEKLY WITH THE ADVISORS AND THE ADVISORS REPORT WEEKLY BY MEMORANDUM TO THE COMMANDING OFFICER VIA THE CHAIN OF COMMAND. THIS WEEKLY MEMO DISCUSSES ACADEMIC, MILITARY OR PERSONAL PROBLEMS THAT THE STUDENTS MAY HAVE.

THE SENIOR STAFF, THE COMMANDING OFFICER, EXECUTIVE OFFICER, AND ACADEMIC DEPARTMENT HEADS, OBSERVE ONE SECTION WEEKLY. THESE OBSERVATIONS COUPLED WITH GRADE REPORTS AND SECTION ADVISOR MEMOS, INSURE THAT THE CHAIN OF COMMAND IS CURRENT ON THE QUALITY OF STUDENT PERFORMANCE AND ON STUDENT PROBLEMS.

VARIOUS ACTIONS ARE AVAILABLE TO ASSIST STUDENT WHO ARE HAVING DIFFICULTIES. THE ACTIONS DESIGNED TO CORRECT ACADEMIC DEFICIENCIES INCLUDE A MANDATORY STUDY PROGRAM IN WHICH STUDENTS ARE ASSIGNED A CERTAIN NUMBER OF HOURS TO STUDY ON A WEEKLY BASIS BASED ON THEIR GRADES. SOME WEAK STUDENTS ARE ASSIGNED WEEKEND REVIEW PACKAGES CONTAINING ADDITIONAL HOMEWORK QUESTIONS TO BE ANSWERED AND REVIEWED. IN ADDITION, STUDENTS ARE ASSIGNED SATURDAY MORNING MAKEUP WORK IF THEY HAVE NOT DEVOTED REASONABLE EFFORT ON THEIR HOMEWORK. WEAK STUDENTS ARE ASSIGNED INSTRUCTOR ASSISTANCE BY THEIR SECTION ADVISOR OR AN INSTRUCTOR FOR PERSONALIZED HELP. THERE ARE MANDATORY EXTRA INSTRUCTION SESSIONS WEEKLY FOR POOR STUDENTS IN EVERY SECTION.

IF REQUIRED, A STUDENT IS GIVEN EXAM FAILURE COUNSELLING. THE INSTRUCTORS AND SECTION ADVISORS REVIEW THE STUDENT'S EXAMINATION TO DETERMINE THE REASONS FOR HIS FAILURE, INCLUDING A CHECK OF HIS STUDY HABITS AND CLASSROOM NOTES. THEY THEN DEVELOP A CORRECTIVE STUDY PROGRAM FOR THE STUDENT.

IF A STUDENT HAS CONTINUALLY FAILED EXAMS HE GOES BEFORE AN ACADEMIC BOARD. THESE ACADEMIC BOARDS GIVE ORAL EXAMINATIONS TO DETERMINE A PARTICULAR STUDENT'S CURRENT LEVEL OF KNOWLEDGE AND HIS POTENTIAL TO SUCCESSFULLY COMPLETE THE COURSE. THE BOARD CAN RECOMMEND RETENTION ON ACADEMIC PROBATION OR THAT THE STUDENT BE DROPPED, DEPENDING ON THE KNOWLEDGE THE STUDENT SHOWS AT THE BOARD.

I approve all officer student disenrollments from Nuclear Power School. A member of my staff approves all enlisted student disenrollments.

STUDENT RECORDS

Complete records are maintained on each student's work at Nuclear Power School. This includes all of the results of his examinations, his progress and every personal counselling session he is given. His comment folder which contains summaries of all counselling sessions while at Nuclear Power School is retained for five years while his class standing and course average is maintained permanently on file.

PROTOTYPE OPERATIONAL TRAINING

OPERATIONAL TRAINING IS CONDUCTED AT EIGHT LAND-BASED NAVAL REACTORS PROTOTYPES. THREE ARE LOCATED AT THE NAVAL REACTORS FACILITY, IDAHO FALLS, IDAHO; FOUR AT WEST MILTON, NEW YORK; AND ONE AT WINDSOR, CONNECTICUT. THESE PROTOTYPES ARE OWNED AND OPERATED BY THE DEPARTMENT OF ENERGY (DOE) PRIMARILY TO PROVIDE RESEARCH AND TEST FACILITIES FOR THE DOE NAVAL REACTORS LABORATORIES. INSTRUCTION IS PROVIDED BY NAVAL PERSONNEL AND BY CIVILIAN PERSONNEL FROM THE NAVAL REACTORS LABORATORIES. THE NAVY PROVIDES SOME OF THE CLASSROOM AND ADMINISTRATIVE FACILITIES TOGETHER WITH MOST OF THE OPERATING CREW FOR THE PROTOTYPE PLANT. THE DOE IN TURN MAKES THE PLANT AVAILABLE FOR TRAINING WHEN IT IS NOT OTHERWISE REQUIRED FOR DEVELOPMENTAL TESTING.

AT THESE PROTOTYPES, THE NAVY PERSONNEL IN TRAINING RECEIVE LECTURES AND ON-THE-JOB INSTRUCTION IN THE PRACTICAL ASPECTS OF REACTOR PLANT OPERATION. THEY OPERATE ALL OF THE EQUIPMENT ASSOCIATED WITH THE REACTOR PLANT UNDER THE SUPERVISION OF QUALIFIED INSTRUCTORS. OFFICERS QUALIFY AS ENGINEERING OFFICER OF THE WATCH. THEY MUST DEMONSTRATE A THOROUGH KNOWLEDGE OF ALL THE REACTOR PLANT AND STEAM PLANT SYSTEMS AS WELL AS THE DETAILED OPERATING CRITERIA AND PROCEDURES, AND DEMONSTRATE THE ABILITY TO PERFORM OPERATIONS ON ALL WATCH STATIONS IN THE PROTOTYPE PLANT; THEY MUST DEMONSTRATE THAT THEY CAN TAKE CHARGE OF THE PLANT AND PUT IT THROUGH NORMAL AND CASUALTY MANEUVERS.

ENLISTED MEN QUALIFY AS OPERATORS OF EQUIPMENT CONNECTED WITH THEIR PARTICULAR RATING. THIS QUALIFICATION CONSISTS OF DEMONSTRATING GENERAL KNOWLEDGE OF ALL REACTOR PLANT SYSTEMS AND DETAILED KNOWLEDGE OF THOSE ASSOCIATED WITH THEIR OWN RATING. THEY MUST QUALIFY ON THE WATCH STATIONS THEY WOULD NORMALLY STAND ABOARD SHIP, AND THEY MUST BE ABLE TO HANDLE NORMAL MAINTENANCE PROBLEMS ON THEIR EQUIPMENT.

I WANT TO MAKE IT CLEAR THAT THIS TRAINING IS ALL CARRIED OUT ON AN OPERATING PROTOTYPE PROPULSION PLANT, NOT ON A REACTOR SIMULATOR. AS FAR AS I AM CONCERNED, YOU CANNOT TAKE AN INEXPERIENCED PERSON AND TRAIN HIM ON A REACTOR SIMULATOR. EVERY TIME HE MAKES A MISTAKE ON A SIMULATOR, THE INSTRUCTOR STOPS AND MERELY MOVES SOME SWITCH BACK TO ITS PROPER POSITION AND THEN GOES ON. ON A SUBMARINE IF YOU MAKE A MISTAKE, THE REACTOR COULD SHUT DOWN WHEN THE SHIP IS SUBMERGED. IF THERE IS AN ENEMY RIGHT THERE, YOU CANNOT COME TO THE SURFACE AND REGROUP. IT IS IMPERATIVE THAT THE TYPE OF TRAINING BE GEARED TO THIS INCREASED LEVEL OF RESPONSIBILITY. YOU HAVE TO TRAIN PEOPLE TO REACT TO THE REAL SITUATION AT ALL TIMES; BUT IF THEY ARE TRAINED WITH A SIMULATOR, THEY TEND TO EXPECT THERE WILL BE NO CONSEQUENCES AS A RESULT OF THEIR ACTIONS. THIS SIMPLY WON'T WORK IN REAL LIFE.

SOME COMPANIES HAVE TRIED TO GET INTO THE BUSINESS OF BUILDING REACTOR SIMULATORS FOR US CLAIMING IT WILL ALLOW US TO TRAIN OUR PEOPLE FAST. THEN THEY CAN GRANT A CERTIFICATE THAT THE NAVY PEOPLE OPERATED A SIMULATOR. BUT I WANT TO KNOW THAT THEY CAN OPERATE A REAL HONEST-TO-GOODNESS REACTOR PLANT.

I WOULD SAY THAT FOR ANYONE DEALING WITH NUCLEAR POWER, IT IS TOO COMPLEX A TECHNOLOGY TO HAVE PEOPLE JUST GET AN IDEA HOW TO OPERATE A REACTOR BY LEARNING HOW TO THROW A FEW SWITCHES THAT CAN BE IMMEDIATELY CHANGED TO CORRECT AN ERROR. THE FACT THAT YOU WILL BE OPERATING A REACTOR IN A SHIP IN COMBAT WHERE PEOPLES' LIVES DEPEND ON YOUR PERFORMANCE GIVES YOU AN ENTIRELY DIFFERENT FEELING ABOUT THE IMPORTANCE OF PROPER TRAINING.

I GO OUT ON THE INITIAL SEA TRIALS OF EVERY NUCLEAR SHIP. MORE THAN HALF THE CREW HAVE NEVER BEEN TO SEA BEFORE. I AM TALKING ABOUT A BRAND NEW SHIP. YET I PUT THEM THROUGH THEIR PACES. I REQUIRE THEM TO EXERCISE THE SHIP AND THE PROPULSION PLANT TO ITS FULLEST. NOW, THIS IS A NEW CREW, AND THEY MUST DO ALL THESE THINGS WHEN THEY HAVE HAD LITTLE OR NO EXPERIENCE AT SEA. THEY HAVE NO OUTSIDERS TO ADVISE THEM, AND THEY MUST BE ABLE TO OPERATE THE SHIP CORRECTLY FOR ME TO BE SATISFIED. THE ONLY WAY THEY CAN DO THIS IS IF THEY HAVE BEEN PROPERLY TRAINED UNDER CIRCUMSTANCES IDENTICAL TO WHAT THEY ENCOUNTER

AT SEA. YOU CANNOT DO THIS WITH SIMULATORS.

INTRODUCTION TO PROTOTYPE TRAINING

TRAINING AT ANY ONE OF THE EIGHT PROTOTYPES IS CONDUCTED THE SAME WAY, AND IS BASED ON A FOUR-PHASE PROGRAM COVERING A 26 WEEK TRAINING PERIOD. A CLASSROOM PHASE, TRANSITION PHASE, IN-HULL PHASE AND PROFICIENCY PHASE MAKE UP THE BASIC PROTOTYPE TRAINING PLAN.

THE STUDENTS ARE ASSIGNED TO ONE OF THE PROTOTYPES UPON COMPLETION OF NUCLEAR POWER SCHOOL. WHEN THE CLASS ARRIVES, IT STARTS CLASSROOM TRAINING WHICH IS PRIMARILY CONDUCTED IN SPACES OUTSIDE THE PROTOTYPE HULL. AFTER FIVE WEEKS, THE STUDENT STARTS MAKING THE TRANSITION INTO THE HULL AND HE THEN BEGINS WATCHSTANDING TRAINING UNDER INSTRUCTION. THIS IS WHAT PROTOTYPE TRAINING IS ALL ABOUT; TO GIVE THE MAN IN-HULL EXPERIENCE OPERATING THE REACTOR PLANT, OPERATING EQUIPMENT VERY MUCH LIKE THAT HE WILL BE OPERATING AT SEA, USING PROCEDURES LIKE THOSE HE WILL BE USING AT SEA. THE MAJOR OBJECTIVE OF PROTOTYPE TRAINING IS TO MAKE THE BEST USE OF THE TRAINING THAT IS DONE IN THE HULL WITHIN THE CONSTRAINTS OF REACTOR SAFETY. AT THE CONCLUSION OF THE WATCHSTANDING TRAINING UNDER INSTRUCTION, THE MAN QUALIFIES BY PASSING WRITTEN AND ORAL EXAMS. THIS ALLOWS HIM TO STAND THE WATCH AND TO OPERATE THE EQUIPMENT ON HIS OWN--WITHOUT THE PRESENCE OF AN INSTRUCTOR. AFTER HE HAS QUALIFIED, AND IN THE PERIOD BEFORE HIS CLASS GRADUATES.

HE STANDS WATCHES TO GAIN PROFICIENCY AS A WATCHSTANDER.

THERE ARE TWO REASONS WHY THE PROGRAM IS BASED ON THESE FOUR PHASES. FIRST, THIS IS A SYSTEMATIC APPROACH TO PREPARE THE MAN TO STAND WATCHES BY GETTING HIM TO LEARN THE SYSTEMS AND COMPONENTS HE WILL BE OPERATING, AND THEN ACTUALLY OPERATING THEM. IT IS A REPETITIVE PROCESS WHICH GOES FROM THEORY, TO HARDWARE FAMILIARITY, TO OPERATION. THE PREPARATION ENABLES A MORE EFFICIENT USE OF THE PROTOTYPE REACTOR PLANT WHEN THE MAN ENTERS THE WATCHSTANDING PHASE.

SECOND, WITH THIS FOUR-PHASE PROGRAM, TWO CLASSES FROM NUCLEAR POWER SCHOOL CAN BE ACCOMMODATED AT THE PLANT AT THE SAME TIME. AGAIN, THIS MAKES FOR THE BEST USE OF THE PROTOTYPE EQUIPMENT. THE TIME ONE CLASS STARTS INTO WATCHSTANDING TRAINING COINCIDES WITH THE TIME THE PREVIOUS CLASS QUALIFIED, AND THE TIME IT ENDS WATCHSTANDING TRAINING COINCIDES WITH THE TIME THE NEXT CLASS STARTS ITS WATCHSTANDING TRAINING.

PROTOTYPE CLASSROOM PHASE

THE CLASSROOM PHASE IS OF FIVE WEEKS DURATION. THIS PHASE CONSISTS PRIMARILY OF LECTURES, COUPLED WITH SOME PRACTICAL TRAINING.

IN THE CLASSROOM PHASE, THE STUDENT SPENDS 12 HOURS A DAY AT THE SITE, MONDAY THROUGH FRIDAY. DURING THIS TIME AN OFFICER GETS ABOUT 7 HOURS A DAY OF LECTURES AND EXAMINATIONS, AND AN ENLISTED MAN ABOUT 6 HOURS PER DAY. THE REMAINING FIVE TO SIX HOURS IS SPENT IN STUDY AT THE SITE.

THE LECTURES COVER THE MECHANICAL, ELECTRICAL, AND REACTOR SYSTEMS THAT ARE SPECIFIC TO THE PLANT TO WHICH THE TRAINEE IS ASSIGNED. IN ADDITION, HE RECEIVES LECTURES IN CHEMISTRY AND RADIOLOGICAL CONTROLS. IN MECHANICAL SYSTEMS, FOR EXAMPLE, THE OFFICER GETS THREE WEEKS OF CLASSROOM INSTRUCTION. ABOUT HALF OF THESE LECTURES COVER PRIMARY PLANT REACTOR MECHANICAL SYSTEMS AND THE OTHER HALF COVER THE SECONDARY STEAM PLANT MECHANICAL SYSTEMS.

YOU MAY ASK WHY THE STUDENT MUST GET SO MUCH CLASSROOM INSTRUCTION, SINCE HE HAS JUST FINISHED NUCLEAR POWER SCHOOL. AT NUCLEAR POWER SCHOOL HE WAS TAUGHT THE THEORETICAL BASIS FOR THE SYSTEMS; FOR EXAMPLE, HEAT TRANSFER AND FLUID FLOW. IN TEACHING THEORY AT NUCLEAR POWER SCHOOL, AN S5W SUBMARINE PLANT WAS USED AS THE PRIMARY EXAMPLE AS IT IS THE MOST NUMEROUS OF THE VARIOUS TYPES OF PROPULSION PLANTS IN USE IN THE FLEET. AT THE PROTOTYPE, THE STUDENT MUST LEARN THE SYSTEMS OF THE SPECIFIC PLANT (S1W, FOR EXAMPLE, IS THE PROTOTYPE OF THE NAUTILUS PROPULSION PLANT AND A1W IS AN AIRCRAFT CARRIER PROTOTYPE) TO WHICH

HE IS ASSIGNED RATHER THAN S5W SYSTEMS. ALTHOUGH THE OVERALL SYSTEM LAYOUTS ARE SIMILAR ON ALL THE PLANTS, THE STUDENT MUST LEARN THE DETAILS ABOUT THE SPECIFIC PLANT HE WILL OPERATE DURING HIS TRAINING AT THE PROTOTYPE.

THE MECHANICAL, ELECTRICAL, AND REACTOR LECTURES ARE ALL ORIENTED TO THE SPECIFIC PROTOTYPE. EACH MAN GETS THESE LECTURES FROM THE VIEWPOINT OF HIS JOB. FOR EXAMPLE, THE OFFICER GETS THESE LECTURES FROM THE VIEWPOINT OF HIS JOB AS A SUPERVISOR WITH REGARD TO THESE SYSTEMS.

AS HE GOES THROUGH THESE LECTURES, THE STUDENT HAS STUDY ASSIGNMENTS TO COMPLETE. WE CALL THESE HOMEWORK; BUT SINCE ALL THIS IS CLASSIFIED MATERIAL. THE STUDENT HAS TO COMPLETE IT AT THE SITE RATHER THAN AT HOME. ONE PART OF THESE STUDY ASSIGNMENTS REQUIRES THE STUDENT TO GET INTO THE HULL AND TRACE OUT THE PLANT SYSTEMS--HAND OVER HAND--FINDING OUT WHAT THEY LOOK LIKE AND WHERE THEY GO.

IN ADDITION TO THE MECHANICAL, ELECTRICAL AND REACTOR SYSTEMS, THE STUDENT GETS CHEMISTRY AND RADIOLOGICAL CONTROLS LECTURES. THE LECTURES IN CHEMISTRY AND RADIOLOGICAL CONTROLS ARE NOT SPECIFIC TO EACH PLANT--SINCE THESE AREAS ARE COMMON TO ALL REACTOR PLANTS. THE OFFICER STUDENT GETS MUCH MORE IN THIS AREA THAN THE ENLISTED STUDENT. THIS IS BECAUSE WE DO NOT TRAIN MOST ENLISTED PERSONNEL TO DO MUCH IN CHEMISTRY AND RADIOLOGICAL CONTROLS,

OTHER THAN WHAT IS NEEDED FOR THEIR OWN PERSONAL SAFETY AND TO DO THEIR JOBS. LATER, ENLISTED SPECIALISTS CALLED ENGINEERING LABORATORY TECHNICIANS ARE TRAINED IN CHEMISTRY AND RADIOLOGICAL CONTROLS. WE HAVE FOUND THAT IT TAKES THREE ADDITIONAL MONTHS TO TRAIN ENLISTED PERSONNEL TO BECOME SPECIALISTS IN THIS AREA. THE OFFICER, HOWEVER, MUST GET MORE AT THIS POINT BECAUSE HE WILL BE SUPERVISING THIS AREA.

WRITTEN EXAMINATIONS OF ONE TO TWO HOURS LENGTH ARE GIVEN EVERY WEEK. THERE IS NO COMPREHENSIVE WRITTEN EXAMINATION AT THE END OF THE CLASSROOM PHASE. INSTEAD, THE WEEKLY EXAM GRADES ARE USED BY THE STAFF TO IDENTIFY WEAK AREAS WHERE THE STUDENT WILL NEED EXTRA WORK. A BANK OF EXAMINATION QUESTIONS AND ANSWER KEYS IS MAINTAINED FOR ALL WRITTEN EXAMINATIONS GIVEN AT THE PROTOTYPE. EACH QUESTION AND ANSWER HAS BEEN REVIEWED INDEPENDENTLY FOR TECHNICAL ACCURACY, CLARITY, SCOPE AND DEPTH OF THE QUESTION. IN ADDITION, THE OVERALL EXAMINATION IS REVIEWED AND APPROVED BEFORE USE.

REQUIREMENTS HAVE BEEN ESTABLISHED ON THE REUSE OF QUESTIONS FROM THE EXAMINATION BANK IN SUBSEQUENT EXAMS. THERE ARE ALSO REQUIREMENTS ON THE TYPES OF QUESTIONS THAT ARE USED. FOR EXAMPLE, NO TRUE AND FALSE QUESTIONS ARE ALLOWED. ESSAY QUESTIONS AND PROBLEMS REQUIRING CALCULATIONS

MUST MAKE UP AT LEAST 40% OF THE EXAM. FINALLY, THE EXAM QUESTIONS AND ANSWERS ARE REVIEWED ANNUALLY FOR TECHNICAL ACCURACY AND CONTENT.

IF A STUDENT FAILS AN EXAMINATION, HE IS ASSIGNED A REMEDIAL UPGRADING PROGRAM TAILORED TO HIS INDIVIDUAL NEEDS. STAFF ADVISORS FOLLOW THE STUDENT'S PROGRESS DAILY TO ENSURE THAT THE REMEDIAL ASSIGNMENTS ARE COMPLETED. STUDENT COUNSELING IS IMPORTANT TO DETECT PROBLEMS EARLY BEFORE THE TRAINEE HAS FALLEN TOO FAR BEHIND. EACH STUDENT RECEIVES PERIODIC INTERVIEWS FROM PLANT SUPERVISORS. INTERVIEWS ARE REQUIRED AT LEAST EVERY TWO WEEKS, UPON ANY EXAMINATION FAILURE, OR FOR GENERALLY LOW GRADES. THE FREQUENCY OF THESE INTERVIEWS INCREASES TO WEEKLY IN LATER PHASES OF TRAINING.

ALL INTERVIEWS AND UPGRADING PROGRAMS ARE DOCUMENTED IN THE STUDENT'S RECORD. THESE RECORDS ARE ESSENTIAL IN THE EVENT THAT WE MUST DISENROLL THE STUDENT.

THE QUALITY OF LECTURES IS ASSURED THROUGH THE USE OF APPROVED LESSON PLANS AND BY MONITORING OF THE LECTURES. EACH INSTRUCTOR IS MONITORED AT LEAST ONCE DURING EACH CLASSROOM PHASE BY SENIOR NAVY OR CONTRACTOR MANAGEMENT. THE MONITOR HAS A COPY OF THE LESSON PLAN WITH HIM, AND HE FILLS OUT AN EVALUATION FORM WHICH IS REVIEWED BY THE INSTRUCTOR AND HIS SUPERVISOR.

PROTOTYPE TRANSITION PHASE

THE PROTOTYPE TRANSITION PHASE STARTS AT WEEK SIX AFTER COMPLETION OF THE CLASSROOM TRAINING. AT THE START OF THE TRANSITION PHASE, THE STUDENTS ARE DIVIDED INTO FOUR GROUPS AND EACH GROUP IS ASSIGNED TO A CREW. THEY GO ON AN EIGHT HOUR ROTATING SHIFT SCHEDULE, SO THERE IS ALWAYS ONE CREW OPERATING AND TRAINING ON THE PLANT, 24 HOURS A DAY AND SEVEN DAYS A WEEK. AFTER THEIR EIGHT HOUR SHIFT AS THE CREW IN THE HULL, THE STUDENTS AND STAFF WORK ADDITIONAL HOURS. THE STUDENTS CONTINUE TO WORK AT LEAST 60 HOURS A WEEK DURING THIS PERIOD.

TWO MAJOR TRAINING EFFORTS ARE INVOLVED IN THE TRANSITION PHASE; SYSTEMS TRAINING, AND THE BEGINNING OF WATCHSTANDING QUALIFICATION. THE SYSTEMS TRAINING REQUIRES MORE DETAILED STUDY THAN THE STUDENT WAS EXPOSED TO IN CLASSROOM PHASE LECTURES. IT IS PRIMARILY A SELF STUDY OF EACH PLANT SYSTEM, FOLLOWED BY A ONE-HALF TO TWO HOUR ORAL CHECKOUT OF THAT SYSTEM. THE STUDENT STARTS STANDING TRAINING WATCHES IN-HULL AT ABOUT THE NINTH WEEK. DURING THE TRANSITION PHASE SOME STUDENTS STAND WATCHES IN-HULL; SOME STUDY FOR A SYSTEM CHECKOUT AND SOME ARE RECEIVING THESE SYSTEM CHECKOUTS.

IN SYSTEMS TRAINING, THE STUDENT FIRST LEARNS THE INDIVIDUAL SYSTEM AND ITS COMPONENTS, THEN THE INTERRELATIONSHIP BETWEEN THE SYSTEMS -- HOW THEY AFFECT OR INTERFACE WITH EACH OTHER -- AND FINALLY HOW TO OPERATE ALL OF THE INDIVIDUAL SYSTEMS AS AN INTEGRATED PLANT. THE DOCUMENT THAT TELLS THE STUDENT WHAT HE

NEEDS TO KNOW ABOUT A PARTICULAR SUBJECT, AND TELLS THE INSTRUCTOR ON WHAT HE SHOULD EXAMINE THE STUDENT, IS CALLED THE QUALIFICATION STANDARD. THE QUALIFICATION STANDARD CONTAINS A PLACE FOR ALL THE CHECKOUT SIGNATURES THE STUDENT MUST GET DURING HIS SIX MONTH PERIOD AT THE PROTOTYPE. THESE SIGNATURES VERIFY THAT THE STUDENT HAS COMPLETED A GIVEN PORTION OF HIS TRAINING. EVENTUALLY THIS BECOMES THE LEGAL RECORD OF THE STUDENTS QUALIFICATION. ONLY AUTHORIZED INSTRUCTORS CAN GIVE THESE SIGNATURES, AND A SYSTEM IS USED WHEREBY CERTAIN SIGNATURES ARE EMBOSSED TO GUARD AGAINST IMPROPER SIGNING OF THE QUALIFICATION RECORD. EXAMPLES OF THE TYPE OF KNOWLEDGE REQUIRED BY THE QUALIFICATION STANDARD FOR A SYSTEM OR COMPONENT ARE "EXPLAIN THE FUNCTIONS OF THE SYSTEM "OR, AFTER HAVING PHYSICALLY TRACED THE SYSTEM IN THE PLANT, "DRAW A ONE-LINE SKETCH OF THE SYSTEM FROM MEMORY; USING APPROPRIATE SYMBOLS AND NOMENCLATURE AND SHOWING THE ITEMS LISTED BELOW."

THE QUALIFICATION STANDARD PLAYS AN EQUALLY IMPORTANT ROLE IN WATCHSTANDING TRAINING AND QUALIFICATION. HERE IT INDICATES THE PRACTICAL FACTORS AND TRAINING WATCH REQUIREMENTS THAT THE STUDENT MUST MEET.

THE SECOND MAJOR TYPE OF TRAINING DURING TRANSITION PHASE IS WATCHSTANDING. TO QUALIFY AT THE PROTOTYPE, ALL STUDENTS ARE REQUIRED TO STAND A GIVEN MINIMUM NUMBER OF WATCHES UNDER THE INSTRUCTION OF QUALIFIED STAFF WATCHSTANDERS. DURING

THESE WATCHES, THE STAFF WATCHSTANDER IS RESPONSIBLE FOR THE WATCH STATION; HOWEVER, HE FULFILLS THIS RESPONSIBILITY BY USING THE STUDENT TO CARRY OUT WATCHSTANDING DUTIES.

DURING THESE WATCHES, THE STUDENT IS EXPECTED TO ACT AS IF HE WERE RESPONSIBLE FOR THAT WATCH. THE STAFF INSTRUCTOR WATCHES EACH MOVE AND STOPS AND CORRECTS THE STUDENT IF HE STARTS TO MAKE A MISTAKE.

THE STUDENT IS GRADED ON EACH WATCH, AND MUST RECEIVE A SATISFACTORY GRADE OR HE DOES NOT GET CREDIT FOR THE WATCH. THE STUDENT IS EXPECTED TO SIGNIFICANTLY IMPROVE HIS WATCH-STANDING CAPABILITY AS HE GAINS EXPERIENCE OF EACH WATCHSTATION. THIS FACTOR IS TAKEN INTO ACCOUNT WHEN ASSIGNING HIM A GRADE.

DURING THE WATCH, THERE ARE PRESCRIBED THINGS THE STUDENT MUST DO, SUCH AS STARTING UP AND SHUTTING DOWN A PIECE OF EQUIPMENT. THESE ARE CALLED "PRACTICAL FACTORS." THE STUDENT DOES THESE UNDER INSTRUCTION, WITH THE STAFF INSTRUCTOR PROVIDING DIRECT SUPERVISION. THE EMPHASIS IS ON THE STUDENT DOING THE OPERATION HIMSELF. THIS IS ACCOMPLISHED BY FIRST TALKING THROUGH THE OPERATION AND THEN LETTING THE STUDENT PERFORM IT. THE STAFF INSTRUCTOR ASKS THE STUDENT SUCH THINGS AS: "HOW ARE YOU GOING TO START UP THAT PUMP?"; "SHOW ME THE PROCEDURE"; "DISCUSS EACH STEP WITH ME"; "WHAT IS THE PURPOSE BEHIND THAT STEP?"; "WHAT WOULD HAPPEN IF YOU DID NOT DO THAT

STEP?"; "WHAT ELSE IN THE PLANT WILL BE AFFECTED BY IT?" THIS SORT OF QUESTIONING IS IMPORTANT BECAUSE IT ALLOWS THE INSTRUCTOR TO DETERMINE IF THE STUDENT UNDERSTANDS WHY HE DOES A PARTICULAR THING, RATHER THAN THE LATTER MERELY KNOWING THAT HE MUST TURN A SWITCH OR OPEN A VALVE.

PROTOTYPE PLANT OPERATIONS ARE SCHEDULED TO COINCIDE WITH THE EXTENT THE CLASS HAS PROGRESSED THROUGH THE TRAINING PROGRAM. FOR THE FIRST STUDENT TRAINING WATCHES, THE PLANT IS HELD IN A STEADY-STATE STEAMING CONDITION. THIS MEANS THE REACTOR IS AT A CONSTANT POWER AND A STEADY-STATE CONDITION EXISTS IN THE ENGINEROOM. LATER ON, THE SCHEDULE CALLS FOR MORE COMPLICATED OPERATIONS, SUCH AS STARTUPS AND SHUTDOWNS OF THE STEAM PLANT, STARTUPS AND SHUTDOWNS OF THE REACTOR, AND CASUALTY DRILLS. IT IS IMPORTANT TO NOTE THAT IN THE CASE OF THE OFFICER STUDENT QUALIFYING AS ENGINEERING OFFICER OF THE WATCH, HE NOT ONLY STANDS TRAINING WATCHES AND COMPLETES PRACTICAL FACTORS AS ENGINEERING OFFICER OF THE WATCH, BUT ALSO STANDS WATCH AT THE ENLISTED WATCH STATIONS AND DOES PRACTICAL FACTORS THERE ALSO.

THIS GIVES THE OFFICER A BETTER OVERALL FEEL FOR WHAT IS HAPPENING THROUGHOUT THE PLANT. AS AN EXAMPLE, AT ONE OF OUR PROTOTYPES THE OFFICER STUDENT MUST STAND A MINIMUM OF ABOUT 180 HOURS OF TRAINING WATCHES OF WHICH SEVENTY PER CENT ARE DEVOTED TO WATCHES OTHER THAN ENGINEERING OFFICER OF THE WATCH.

DURING WATCHSTANDING TRAINING, THE STUDENT IS ALSO INSTRUCTED ON PROPER COMMUNICATIONS PROCEDURES AND FORMALITY IN COMMUNICATIONS. HE IS ALSO INSTRUCTED IN LOGKEEPING AND OTHER NORMAL DUTIES OF A WATCHSTANDER.

OTHER TRAINING CONDUCTED DURING THE TRANSITION PHASE INCLUDE LECTURES, SEMINARS AND TRAINING EXERCISES. A SERIES OF LECTURES ARE GIVEN WHICH ARE DETAILED AND SPECIFIC FOR EACH ENLISTED RATING, AND FOR THE OFFICERS. THESE LECTURES ARE GIVEN ON SUBJECTS WHERE EXPERIENCE HAS SHOWN THAT MORE EMPHASIS IS NEEDED TO GET THE MESSAGE THROUGH TO THE STUDENT. THIS SERIES IS ABOUT 40 HOURS LONG. FOR OFFICERS IT COVERS REACTOR PLANT INSTRUMENTS AND CONTROL, ELECTRICAL EQUIPMENT AND CONTROL, AND THE MAIN TURBINE.

TWO OTHER TYPES OF TRAINING ARE STARTED DURING TRANSITION PHASE: SEMINARS AND TRAINING EXERCISES. EXPERIENCE HAS SHOWN THAT TRAINING IN DIFFERENT FORMS IS NECESSARY TO PROVIDE A SOUND BASIS FOR OPERATION AND FOR THE KINDS OF ENGINEERING JUDGEMENT THAT WILL BE NEEDED AT SEA. IN ADDITION, REPETITION AND DIFFERENT FORMS OF TRAINING ARE REQUIRED TO OBTAIN ADEQUATE RETENTION.

IN THE TRANSITION PHASE, THE STUDENT RECEIVES TRAINING THROUGH SEMINARS. THESE SEMINARS ARE REQUIRED ON WATCHSTANDING PRINCIPLES, SUCH AS

WATCH RELIEF PROCEDURES, COMMUNICATIONS, FORMALITY, PROCEDURAL COMPLIANCE, TAGOUTS, CASUALTY CONTROL, LOGS, AND PLANT AWARENESS. ALSO, SEMINARS ARE REQUIRED ON REACTOR STARTUP AND SHUTDOWN.

A SEMINAR IS NOT A LECTURE. THE IDEA OF SEMINAR TRAINING IS TO GET THE STUDENTS INVOLVED. THEY MUST PARTICIPATE IN AN ACTIVE MANNER, AND SHOW SATISFACTORY KNOWLEDGE. OTHERWISE THEY DO NOT RECEIVE CREDIT FOR PARTICIPATING. WE HAVE MADE A STRONG EFFORT TO ENFORCE THE IDEA THAT A SEMINAR IS NOT A LECTURE, BUT MORE LIKE A "DRILL IN THE CLASSROOM." THESE SEMINARS ARE DESIGNED TO GET THE STUDENT TO THINK HIS WAY THROUGH A PROBLEM AND REACH A SOLUTION. AS WITH ALL OTHER TRAINING, THERE ARE WRITTEN REQUIREMENTS FOR THE CONDUCT OF SEMINARS. FOR EXAMPLE, AN APPROVED SEMINAR GUIDE MUST BE FOLLOWED BY THE INSTRUCTOR, WHO IS CALLED THE SEMINAR LEADER AND WHO HAS BEEN FORMALLY TRAINED AND QUALIFIED TO CONDUCT SEMINARS. IN ADDITION, THE NUMBER OF STUDENTS IS RESTRICTED TO SEVEN, AS THIS HAS BEEN SHOWN BY EXPERIENCE TO BE THE MAXIMUM NUMBER OF PARTICIPANTS FOR AN EFFECTIVE SEMINAR.

THE OTHER TYPE OF TRAINING STARTED DURING THE TRANSITION PHASE IS "TRAINING EXERCISES." THESE ARE SESSIONS OF ONE TO FOUR HOURS DURATION IN WHICH THE STUDENT PARTICIPATES IN TRAINING OUTSIDE THE HULL. THESE ARE LIMITED TO GROUPS OF SEVEN OR EIGHT STUDENTS WITH AN INSTRUCTOR. WE HAVE FOUND THAT TRAINING EXERCISES WHERE THERE IS MUCH REPETITION IS

REQUIRED FOR THE STUDENTS TO BECOME REASONABLY PROFICIENT IN CERTAIN SKILLS.

ALL STUDENTS PARTICIPATE IN TRAINING EXERCISES COVERING SUCH THINGS AS DAMAGE CONTROL, WHERE THE STUDENT DONS AND TAKES OFF EMERGENCY BREATHING EQUIPMENT, AND USE OF FIRE FIGHTING EQUIPMENT. ALSO TRAINING IS CONDUCTED IN WHICH THE STUDENT DEMONSTRATES PROPER TECHNIQUES FOR WORKING WITH RADIOLOGICAL CONTROLS. EACH TRAINING EXERCISE IS CONDUCTED USING A PLAN, EACH IS GRADED AND MUST BE SATISFACTORILY PASSED TO GET A SIGNATURE. WHILE HE IS AT THE PROTOTYPE, THE STUDENT WILL GET SEVENTEEN TRAINING EXERCISES TOTALING FIFTY-SIX HOURS. DURING TRANSITION PHASE HE GETS ABOUT TWENTY HOURS.

FINALLY, WRITTEN EXAMINATIONS ARE GIVEN AT THE END OF THE TRANSITION PHASE. AS IN THE CLASSROOM PHASE, THE STUDENT IS ASSIGNED A REMEDIAL PROGRAM IF HE DOES NOT PASS.

DURING TRANSITION PHASE IT IS IMPORTANT TO CAREFULLY FOLLOW THE PROGRESS OF EACH STUDENT'S TRAINING. SEVERAL METHODS ARE USED TO FOLLOW PROGRESS. FIRST, CONSIDERABLE EFFORT IS EXERTED TO PLAN AND SCHEDULE THE TRAINING. THIS BECOMES PARTICULARLY IMPORTANT AT THE START OF THE TRANSITION PHASE, BECAUSE OF THE MANY DIFFERENT TYPES OF TRAINING GIVEN DURING THIS PHASE, THE CONSIDERABLE SELF-STUDY REQUIRED, THE INDIVIDUALS CHECKOUTS, AND THE WATCHSTANDING REQUIREMENTS.

PLANNING STARTS WITH A NINE MONTH ACTIVITY SCHEDULE. THIS SCHEDULE LAYS OUT FOR EACH PLANT THE OPERATING TIME AND THE TIME THE PLANT IS SCHEDULED TO BE SHUTDOWN FOR MAINTENANCE OR CONDUCTING SPECIAL TESTING.

BASED ON THIS NINE MONTH ACTIVITY SCHEDULE, A DETAILED TRAINING EVENTS SUMMARY CHART IS DEVELOPED. THIS SUMMARY IS THEN BROKEN DOWN INTO WEEKLY SCHEDULES FOR EACH CREW, WHICH ARE PREPARED AND APPROVED EACH WEEK BY THE PLANT TRAINING MANAGER. THESE WEEKLY SCHEDULES LIST STUDENT AND INSTRUCTOR ASSIGNMENTS BY NAME.

THE PLANT EVOLUTIONS ARE SCHEDULED ON A SHIFT-BY-SHIFT BASIS FOR THE WEEK, IN SUCH A WAY AS TO PHASE IN THE OPERATIONS AND TRAINING NEEDS. WATCH BILLS ARE ISSUED FOR THE STAFF INSTRUCTORS MANNING THE WATCH, AND A STUDENT WATCH BILL IS ALSO ISSUED FOR THE TRAINEES AT THOSE WATCH STATIONS.

INDIVIDUAL STUDENT PROGRESS IS FOLLOWED ON A DAILY BASIS. IN THE QUALIFICATION SIGNATURE BOOK A POINT VALUE IS ESTABLISHED FOR SIGNATURES RECEIVED BY THE STUDENT. HE IS REQUIRED TO GET A GIVEN NUMBER OF POINTS AS HE PROGRESSES THROUGH THE TRAINING. HE MUST STAY UP WITH HIS EXPECTED PROGRESS CURVE; IF HE FALLS TOO FAR BEHIND, HE WILL BE ASSIGNED REMEDIAL PROGRAMS WHICH MAY REQUIRE HIM TO SPEND EXTRA HOURS AT THE PROTOTYPE.

FINALLY, SURVEILLANCE INSPECTIONS AND PERIODIC AUDITS ARE CONDUCTED TO ASSURE THAT THE TRAINING PROGRAM IS BEING CONDUCTED AS PLANNED. THESE AUDITS GET INTO EVERY PHASE OF THE TRAINING BY USING A PRE-SELECTED AUDIT PLAN. I WILL DISCUSS THE AUDIT SYSTEM LATER.

PROTOTYPE IN-HULL PHASE

THE THIRD PHASE OF PROTOTYPE TRAINING IS THE IN-HULL PHASE. EARLY IN THE PERIOD, THE STUDENT WILL FINISH HIS SYSTEMS CHECKOUTS. BY THIS TIME HE WILL HAVE SPENT ABOUT FOUR HOURS LEARNING AND BEING CHECKED OUT ON EACH OF ABOUT 60 SYSTEMS. THE STUDENT ALSO COMPLETES HIS WATCHSTANDING REQUIREMENTS. WATCHES ARE PLANT CONTROLLING AND CANNOT BE WASTED. IF STUDENTS DO NOT PREPARE, THE FULL BENEFIT OF THE TRAINING WILL NOT BE REALIZED. AT THIS POINT THE STUDENT IS USUALLY TOO INEXPERIENCED TO GRASP THE COMPLEXITY OF THE WATCH STATION AND, THEREFORE, HE MUST BE GUIDED IN HIS STUDY. THIS IS DONE IN SEVERAL WAYS. FIRST, THE STUDENT KNOWS WHICH WATCH HE WILL BE STANDING BECAUSE HE IS ASSIGNED TO IT BY THE STUDENT WATCH BILL. HE WILL ALSO KNOW WHAT OPERATIONS ARE SCHEDULED IN THE PLANT.

SECOND, FOR EACH WATCH, THE STUDENT MUST COMPLETE PRE-WATCH HOMEWORK ASSIGNMENTS THAT RELATE TO THE PLANT OPERATING OR CASUALTY PROCEDURES THAT WILL BE USED DURING THE WATCH. THIRD, BEFORE STANDING A TRAINING WATCH DURING WHICH THE WATCH DUTIES

ARE ACTUALLY ASSUMED, THE STUDENT STANDS A NUMBER OF WATCHES AS AN OBSERVER, TO NOTE WHAT IS GOING ON. IN SOME OBSERVER WATCHES A SEPARATE STAFF INSTRUCTOR IS ASSIGNED TO PROVIDE MORE DETAILED TRAINING FOR THE STUDENT. THIS IS TO ACCELERATE THE STUDENT'S ACQUISITION OF KNOWLEDGE BEFORE HE ACTUALLY STANDS THE WATCH. FINALLY, THE STUDENT ASSUMES THE TRAINING WATCH UNDER INSTRUCTION.

EACH WATCH IS GRADED AND THE STUDENT MUST RECEIVE A SATISFACTORY GRADE TO GET CREDIT FOR THE WATCH. A STUDENT MUST STAND A SPECIFIED MINIMUM NUMBER OF SATISFACTORY WATCHES IN ORDER TO QUALIFY. FOR EXAMPLE, FOR AN OFFICER STUDENT TEN SATISFACTORY WATCHES ARE REQUIRED AT THE ENGINEERING OFFICER OF THE WATCH (EOOW) WATCH STATION. MOST STUDENTS STAND MORE THAN THE MINIMUM NUMBER IN ORDER TO BECOME SUFFICIENTLY PROFICIENT TO PASS THE FINAL EVALUATED WATCH.

A STANDARD FORM IS USED TO EVALUATE EACH WATCH. THIS FORM REQUIRES THE STUDENT TO BE GRADED IN NINE SPECIFIC AREAS. IF HE FAILS A WATCH, HE IS ASSIGNED A REMEDIAL PROGRAM WHICH REQUIRES THE STUDENT TO DO THINGS DIRECTLY RELATED TO THAT WATCH AND HE MUST COMPLETE THIS PROGRAM BEFORE HIS NEXT WATCH ON THAT STATION.

OFFICERS RECEIVE A FINAL EVALUATED WATCH WHICH MUST BE PASSED IN ORDER TO QUALIFY. THIS IS EVALUATED BY A BOARD

COMPOSED OF THREE PEOPLE: ONE OF MY REPRESENTATIVES FROM THE LOCAL NAVAL REACTORS FIELD OFFICE, A SENIOR REPRESENTATIVE OF THE PLANT MANAGEMENT, AND THE STAFF ENGINEERING OFFICER OF THE WATCH ON-WATCH INSTRUCTOR. THIS THREE MAN BOARD IS CONVENED FOR THE PURPOSE OF OBSERVING THE STUDENT'S PERFORMANCE DURING THIS WATCH. EACH OF THE THREE BOARD MEMBERS INDEPENDENTLY GRADES THE WATCH. THE STUDENT MUST RECEIVE A PASSING GRADE FROM ALL THREE. AS PREVIOUSLY POINTED OUT, THE STUDENT MUST PASS THIS WATCH IN ORDER TO QUALIFY.

I HAVE CERTAIN OPERATING PHILOSOPHIES THAT RELATE TO STUDENT WATCHSTANDING: THE PLANTS ARE OPERATED BY DETAILED WRITTEN PROCEDURES. STRICT COMPLIANCE TO THESE PROCEDURES IS REQUIRED AND ENFORCED. THE SHIPBOARD PLANT OPERATING MANUALS CONTAIN THESE PROCEDURES. A STRONG EFFORT HAS BEEN MADE TO MAKE THE PROTOTYPE MANUALS AS MUCH LIKE THOSE USED ON THE SHIPS AS POSSIBLE.

THIS IS ESSENTIAL IN THE OVERALL TRAINING OF THE STUDENT. HE SEES THE SAME KINDS OF OPERATING PROCEDURES, HE USES THE SAME KINDS OF EQUIPMENT RIGHT DOWN TO THE SAME TORQUE WRENCH, FOR EXAMPLE; HE IS TRAINED TO THE SAME KINDS OF QUALIFICATION STANDARDS AND USE THE SAME TEXT BOOKS AS ARE USED THROUGHOUT THE NAVAL NUCLEAR PROGRAM, INSOFAR AS THIS IS POSSIBLE.

EQUIPMENT IS LOGGED AND MONITORED JUST AS IT IS DONE ON

BOARD SHIP. I REQUIRE THAT THE PROTOTYPE PLANT BE OPERATED JUST AS WOULD A SHIP AT SEA, TO THE GREATEST EXTENT POSSIBLE. IN THIS WAY, STUDENTS GET THE ACTUAL LIVE EXPERIENCE OF KNOWING WHAT TO DO WHEN VALVES LEAK OR EQUIPMENT DOES NOT WORK, JUST AS THOUGH IT WERE HAPPENING AT SEA.

DURING THE IN-HULL PERIOD THE STUDENT FINISHES THE SEMINARS AND TRAINING EXERCISES THAT ARE REQUIRED FOR QUALIFICATION. THESE SEMINARS AND TRAINING EXERCISES INVOLVE MORE COMPLEX OPERATIONS AND CASUALTIES. THE STUDENT MUST SHOW THAT HE KNOWS WHAT IS EXPECTED TO OCCUR DURING CHANGING PLANT CONDITIONS, AND THAT HE CAN RECOGNIZE THE SYMPTOMS OF CASUALTIES AND TAKE THE PROPER CORRECTIVE ACTIONS.

DURING THIS PERIOD, THE STUDENT ALSO PARTICIPATES IN ABOUT 65 HOURS OF DISCUSSIONS WITH A STAFF INSTRUCTOR DURING WHICH HE TALKS THROUGH VARIOUS OPERATING AND CASUALTY PROCEDURES. IN GENERAL, THESE ARE THE PROCEDURES WHICH DO NOT ARISE DURING WATCHSTANDING. IF THE STUDENT HAS ALREADY DONE ANY OF THOSE WHILE HE WAS ON WATCH, HE NEED NOT REPEAT THEM.

IN THE LAST FEW WEEKS BEFORE QUALIFICATION, THE STUDENT RECEIVES A DETAILED REVIEW OF THE INTEGRATED PLANT. HE AND A STAFF ENGINEERING OFFICER OF THE WATCH GO OVER THE ENTIRE PLANT OPERATIONS, INCLUDING HOW THE INDIVIDUAL SYSTEMS ARE TIED TOGETHER AND HOW THEY INTERACT OR INTERFACE WITH ONE

ANOTHER. THESE DISCUSSIONS ARE STRUCTURED TO INCREASE THE STUDENT'S OVERALL PLANT KNOWLEDGE AND TO PREPARE HIM FOR HIS FINAL ORAL BOARD.

AT END-OF-CARD CHECKOUT THE STUDENT IS CONDUCTED BY A STAFF INSTRUCTOR FOR TWO HOURS IN EACH OF SIX AREAS. BY "END-OF-CARD" I MEAN THAT THE STUDENT HAS COMPLETED ALL OF THE REQUIRED TRAINING IN THE QUALIFICATION STANDARD. THESE CHECKOUTS ARE DONE JUST PRIOR TO FINAL ORAL BOARDS. THEY COVER MECHANICAL, ELECTRICAL, AND REACTOR OPERATIONS; THE STEAM PLANT, THE CHEMISTRY AND RADIOLOGICAL CONTROL AREAS, AND INTEGRATED PLANT OPERATIONS.

FINALLY, DURING THE IN-HULL WATCHSTANDING PERIOD, EACH STUDENT GETS WHAT IS CALLED A PROGRESS ORAL BOARD WHEN HE IS ABOUT 50% AND 80% OF THE WAY THROUGH QUALIFICATION. THESE BOARDS ARE ONE TO TWO HOURS LONG AND ARE CONDUCTED IN THE SAME MANNER AS A FINAL QUALIFICATION BOARD.

PROGRESS OF THE CLASS AND OF EACH STUDENT IS AGAIN CAREFULLY MONITORED DURING IN-HULL TRAINING. HERE WE LOOK FOR HOW WELL HE IS PROGRESSING IN HIS WATCHESTANDING, TRAINING AREAS, DISCUSSIONS, ETC. IF A STUDENT FALLS BEHIND HE WILL BE ASSIGNED REMEDIAL PROGRAMS.

PROTOTYPE QUALIFICATION CRITERIA

UP TO THIS POINT IN THE TRAINING PROGRAM THE STUDENT'S PROGRESS HAS BEEN MEASURED ALMOST ENTIRELY BY WRITTEN EXAMINATIONS. AS HE MOVES INTO THE ACTUAL PROCESS OF QUALIFYING ON THE PROTOTYPE REACTOR PLANT, THE METHODS OF MEASURING HIS KNOWLEDGE AND ABILITY CHANGE. HE IS NOW REQUIRED TO DEMONSTRATE HIS PERFORMANCE BY THREE DIFFERENT MEANS: WATCHSTANDING ABILITY, KNOWLEDGE AS DEMONSTRATED ON A COMPREHENSIVE WRITTEN EXAMINATION, AND KNOWLEDGE DEMONSTRATED ON AN ORAL BOARD. DIFFERENT PEOPLE AT THE PROTOTYPE ARE INVOLVED IN MAKING THESE EVALUATIONS. THEY ARE NOT BASED ON AN INDIVIDUAL DECISION. EACH WATCH IS USUALLY GRADED BY DIFFERENT PEOPLE, WHILE THE FINAL EVALUATED WATCH REQUIRES A UNANIMOUS GROUP DECISION FOR QUALIFICATION.

THE WRITTEN COMPREHENSIVE EXAM CONSISTS OF QUESTIONS SELECTED SO THAT EACH WRITTEN EXAMINATION IS DIFFERENT. ADDITIONALLY, THE THREE MEMBERS OF THE FINAL ORAL BOARD MUST UNANIMOUSLY AGREE THAT THE INDIVIDUAL IS QUALIFIED.

THIS BRINGS ME TO THE MEANING OF QUALIFICATION. IT IS A PASS/FAIL GRADE FOR THE STUDENT. IF HE PASSES IT MEANS THAT

THE PLANT STAFF, BOTH NAVY AND THE CONTRACTOR, ARE WILLING TO LET HIM STAND THE WATCH ON HIS OWN. IT MEANS THAT THE PLANT MANAGER IS WILLING TO ASSUME RESPONSIBILITY FOR SAFETY OF THE PLANT WHEN IT IS BEING OPERATED BY THIS QUALIFIED STUDENT. THE CONTRACTOR IS THUS SAYING THAT FROM A REACTOR SAFETY VIEWPOINT HE IS WILLING TO LET THE MAN OPERATE THE PLANT. IF THE CONTRACTOR CAN NOT SAY THIS, THEN OBVIOUSLY WE SHOULD NOT LET HIM GO ON TO OPERATE A SUBMARINE OR SURFACE SHIP IN THE FLEET.

THERE ARE FOUR PERFORMANCE AREAS THAT THE STUDENT MUST PASS TO BECOME QUALIFIED:

FIRST, THE STUDENT MUST HAVE A SATISFACTORY FINAL WATCHSTANDING GRADE. I HAVE MENTIONED THAT EACH WATCH WAS GRADED. THIS GRADE IS THE AVERAGE RECEIVED FOR THE WATCHES HE STOOD UNDER INSTRUCTION. THE GRADING BECOMES MORE SEVERE FOR LATER WATCHES AS MORE IS EXPECTED OF THE STUDENT AND THE PLANT OPERATIONS BECOME MORE COMPLEX.

SECOND, FOR OFFICER STUDENTS, A FINAL EVALUATED WATCH MUST BE PASSED. THIS IS DONE BY A BOARD OF THREE MEMBERS AS NOTED PREVIOUSLY. IF THE STUDENT FAILS THIS WATCH, HE COMPLETES REMEDIAL TRAINING AND TRIES AGAIN, AFTER BEING UPGRADED IN HIS WEAK AREAS. TYPICALLY, HE WILL NOT BE GIVEN MORE THAN TWO TO THREE CHANCES BEFORE A DECISION IS MADE ON WHETHER HE SHOULD BE DISENROLLED.

THIRD, THE STUDENT MUST PASS A FINAL COMPREHENSIVE WRITTEN EXAMINATION. THESE ARE DRAWN FROM AN EXAMINATION BANK AND COVER EACH OF THE AREAS OF MECHANICAL, ELECTRICAL, REACTOR, CHEMISTRY, RADIOLOGICAL CONTROLS, AND THE OVERALL PLANT. THE EXAM IS FOUR HOURS IN LENGTH FOR ENLISTED PERSONNEL AND EIGHT HOURS FOR OFFICERS. THESE EXAMINATIONS ARE GRADED AND REVIEWED WITH THE STUDENT PRIOR TO HIS FINAL ORAL BOARD. IF THE STUDENT FAILS IN ANY AREA, HE IS REEXAMINED AFTER AN UPGRADING PROGRAM. IF HE FAILS A REEXAMINATION, HE WILL NORMALLY BE DISENROLLED FROM THE SCHOOL.

LASTLY, EACH STUDENT RECEIVES A FINAL ORAL BOARD. THIS IS A GOOD TECHNIQUE FOR PROBING HIS KNOWLEDGE IN DEPTH; IT IS MUCH EASIER, IN THIS WAY TO ASSESS WHAT THE STUDENT ACTUALLY KNOWS, SINCE EVERY FLAW IN HIS ANSWERS CAN BE NOTED. ANY SIGNIFICANT KNOWLEDGE WEAKNESS IN REACTOR SAFETY WILL CAUSE THE STUDENT TO FAIL THE BOARD.

MEMBERS OF THE ORAL BOARD ARE ALERTED TO THE STUDENT'S WEAK AREAS BY HAVING REVIEWED HIS RECORD. THEY CAN THEREFORE PROBE AREAS IN SUFFICIENT DEPTH. ONLY SPECIFIC PERSONNEL ARE AUTHORIZED TO PARTICIPATE AS BOARD MEMBERS. FOR OFFICER STUDENTS, FOR EXAMPLE, THE FINAL BOARD IS COMPOSED OF FOUR MEMBERS: A MEMBER OF THE CONTRACTOR PLANT MANAGEMENT; A MEMBER OF MY NAVAL REACTORS FIELD OFFICE STAFF OR THE NUCLEAR

POWER TRAINING UNIT STAFF; A COMMISSIONED OFFICER FROM THE PLANT STAFF; AND AN ENGINEERING OFFICER OF THE WATCH. A FAILING GRADE ASSIGNED IN ANY AREA BY ANY BOARD MEMBER CAUSES THE STUDENT TO FAIL THE BOARD.

IN THE EVENT OF FAILURE, HE WILL BE GIVEN A RE-BOARD AFTER REMEDIAL TRAINING. FOR THE RE-BOARD, THE MEMBERS REQUIRED ARE HIGHER LEVEL MANAGERS. FOR EXAMPLE, FOR THE RE-BOARD OF AN OFFICER STUDENT, USUALLY THE PLANT MANAGER, ONE OF MY REPRESENTATIVES FROM THE LOCAL NAVAL REACTORS FIELD OFFICE, THE COMMANDING OFFICER OF THE NUCLEAR POWER TRAINING UNIT AND ANOTHER COMMISSIONED OFFICER WILL BE THE BOARD MEMBERS. IF A STUDENT FAILS HIS SECOND BOARD, HE WILL USUALLY BE DISENROLLED. IN SOME CASES I MAY APPROVE A THIRD BOARD.

THE ORAL BOARDS ARE CONDUCTED FORMALLY. THERE IS A CHAIRMAN OF THE BOARD. THE BOARD EXAMINES THE STUDENT'S RECORD. EACH MEMBER ASK QUESTIONS. ALL MEMBERS GRADE THE ANSWER. THE QUESTIONING CONTINUES UNTIL ALL ARE SATISFIED. FOR AN OFFICER, THIS USUALLY TAKES TWO TO THREE HOURS.

PROTOTYPE PROFICIENCY PHASE

ONCE HE HAS QUALIFIED, THE STUDENT ENTERS THE FOURTH AND LAST PHASE OF TRAINING AT THE PROTOTYPE. THIS IS THE PROFICIENCY PHASE. THE PRIMARY PURPOSE OF THIS PHASE IS TO

BECOME PROFICIENT AS A WATCHSTANDER. IN THIS PHASE THE STUDENT GETS WATCHSTANDING EXPERIENCE AS THE MAN ON WATCH AT THE STATION. HE TAKES THE WATCH BY HIMSELF, AND THERE IS NO STAFF WATCH STANDER PRESENT TO HELP HIM.

LECTURES ARE ALSO SCHEDULED TO INCREASE THE STUDENT'S KNOWLEDGE IN VARIOUS AREAS. IN ADDITION THE QUALIFIED STUDENT HAS AN OPPORTUNITY TO PARTICIPATE IN VARIOUS MAINTENANCE TASKS.

FOR THIS PART OF THE PROGRAM, THE LECTURES AND TASKS ARE SCHEDULED ON A CASE BASIS. THE OBJECT IS TO GIVE STUDENTS AS MUCH ADDITIONAL TRAINING AS WE CAN WHILE HE IS GAINING WATCH-STANDING EXPERIENCE. OBVIOUSLY, NOT ALL STUDENTS GET THE SAME AMOUNT OF PROFICIENCY TRAINING, SINCE THEY QUALIFY AT DIFFERENT TIMES.

THE ENTIRE CLASS GRADUATES AT THE SAME TIME AND ARE TRANSFERRED TO THE FLEET. A SMALL NUMBER OF THOSE WHO HAVE DEMONSTRATED ABOVE AVERAGE PERFORMANCE AT THE NUCLEAR POWER SCHOOL AND THE PROTOTYPE ARE RETAINED ON THE STAFF TO QUALIFY AS INSTRUCTORS.

I HAVE DESCRIBED THE PATH A STUDENT TAKES TO COMPLETE HIS PROTOTYPE QUALIFICATIONS. THERE ARE SOME OTHER AREAS RELATED TO THE PROTOTYPE AND THE TRAINING THERE THAT I WILL DISCUSS.

CONTROL OF THE PROTOTYPE TRAINING PROGRAM

THE PRIMARY CONTROL OF PROTOTYPE TRAINING PROGRAM IS THE PROTOTYPE TRAINING MANUAL. BOTH BETTIS AND KAPL LABORATORIES PARTICIPATED IN PREPARATION OF THIS DOCUMENT BEFORE NAVAL REACTORS APPROVED AND ISSUED IT. THIS ADMINISTRATIVE MANUAL COVERS ALL THE BASIC REQUIREMENTS FOR RUNNING THE PROGRAM. IT RANGES FROM THE ORGANIZATION AND TITLES OF PEOPLE INVOLVED, TO DETAILED DESCRIPTIONS OF HOW THE PROGRAM IS CONDUCTED. IT COVERS PREPARATION AND CONTROL OF ALL THE MATERIALS USED; INCLUDING, FOR EXAMPLE, WHAT MUST BE IN A LESSON PLAN, HOW IT IS ORGANIZED, WHO APPROVES IT, AND SO ON. IT COVERS THE PRIMARY ACADEMIC STANDARDS AND POLICIES.

BASED ON THE NAVAL REACTORS PROTOTYPE TRAINING MANUAL, APPROVED LOCAL PROTOTYPE TRAINING MANUALS HAVE BEEN DEVELOPED FOR EACH PROTOTYPE SITE. THIS ALLOWS SOME FLEXIBILITY TO TAKE ACCOUNT OF SITE DIFFERENCES. HOWEVER, ANY SIGNIFICANT DEVIATION REQUIRES THE APPROVAL OF NAVAL REACTORS.

STUDENT RECORDS

AS IN THE CASE OF THE NUCLEAR POWER SCHOOL, COMPLETE AND DETAILED RECORDS ARE KEPT ON EACH STUDENT FOR ALL OF HIS WORK AT THE PROTOTYPES. SAMPLE EXAMINATIONS USED FOR QUALIFICATION, HIS QUALIFICATION STANDARD, RESULTS OF ORAL EXAMINATIONS, AND

HIS COUNSELLING RECORDS, ARE ALL MAINTAINED FOR FIVE YEARS WHILE A SUMMARY OF HIS RECORD IS MAINTAINED FOR 20 YEARS. AS AN EXAMPLE, OF THE RECORDS MAINTAINED, EACH STUDENT MUST OBTAIN SOME ONE THOUSAND INSTRUCTOR SIGNATURES ATTESTING TO BEING WATCHSTATION QUALIFICATION THROUGHOUT HIS SIX MONTHS TRAINING AT THE PROTOTYPE. THESE RECORDS ARE RETAINED FOR FIVE YEARS AS PART OF THE STUDENT'S RECORD.

QUALIFICATION GUIDES

I HAVE DISCUSSED QUALIFICATION STANDARDS, WHICH ARE LOCAL DOCUMENTS ISSUED BY EACH PROTOTYPE PLANT. THESE STANDARDS ARE BASED UPON QUALIFICATION GUIDES WHICH ARE ALSO APPROVED BY NAVAL REACTORS FOR USE AT ALL PROTOTYPES. THE LOCAL STANDARD IS EXACTLY THE SAME AS THE NAVAL REACTORS GUIDES EXCEPT FOR DEVIATIONS TO ALLOW FOR A GIVEN PLANT'S DESIGN DIFFERENCES. ANY DEVIATIONS FROM THE NAVAL REACTORS ISSUED GUIDE REQUIRES NAVAL REACTORS APPROVAL.

PROTOTYPE ORGANIZATION

THE PROTOTYPE SITES ARE OPERATED BY A CONTRACTOR SITE MANAGER, AND THE INDIVIDUAL PROTOTYPE PLANTS ARE SUPERVISED BY A CONTRACTOR PLANT MANAGER. HE HAS TRAINING, MAINTENANCE, AND ADMINISTRATIVE GROUPS UNDER HIM THAT OPERATE AND MAINTAIN THE PLANTS, AND TRAIN THE STUDENTS. THESE GROUPS ARE A MIXTURE OF

CIVILIAN AND NAVY PERSONNEL. THE WINDSOR, CONNECTICUT SITE IS SLIGHTLY DIFFERENT IN THAT THERE IS NO CIVILIAN PLANT MANAGER. THE PROTOTYPE IS OPERATED BY THE NAVY WITH A NAVAL OFFICER IN CHARGE WHO HAS HAD COMMAND OF A NUCLEAR SHIP.

AS I HAVE MENTIONED, THE PROTOTYPE PLANTS ARE OPERATED ON A FOUR CREW BASIS AROUND THE CLOCK. BOTH NAVY AND CONTRACTOR PERSONNEL ARE ASSIGNED TO CREW AND STAFF WATCHES. THE CONTRACTOR SHIFT SUPERVISOR ON EACH CREW IS THE ON-SHIFT SENIOR CONTRACTOR WATCH, AND SUPERVISES OVERALL OPERATION OF THE PLANT. AGAIN, THE WINDSOR ORGANIZATION HAS A NAVAL OFFICER IN A SIMILAR CAPACITY.

I HAVE MENTIONED THE NUCLEAR POWER TRAINING UNIT (NPTU). THIS IS THE NAVY MILITARY ORGANIZATION AT EACH PROTOTYPE SITE THAT MILITARILY CONTROLS THE NAVAL PERSONNEL. THE COMMANDING OFFICER OF THE NPTU HAS PREVIOUSLY SERVED AS THE COMMANDING OFFICER OF A NUCLEAR POWERED SHIP. HE IS RESPONSIBLE FOR THE MILITARY PERFORMANCE OF THE NAVY PERSONNEL AT THE SITE. HE IS ALSO RESPONSIBLE TO ME TO SEE THAT TRAINING IS BEING PROPERLY CONDUCTED.

IN THE CASE OF THE WINDSOR PROTOTYPE, THE COMMANDING OFFICER, NPTU IS ALSO COMMANDING OFFICER OF THE PROTOTYPE FOR OPERATING THE PLANT. A CONTRACTOR ORGANIZATION IS THERE WITH A SITE MANAGER, BUT THE CIVILIAN ORGANIZATION DOES NOT OPERATE THE PLANT. BOTH THE COMMANDING OFFICER OF EACH NPTU AND HIS

EXECUTIVE OFFICER MONITOR THE PLANT, ACT AS MEMBERS OF VARIOUS QUALIFICATION BOARDS, AND CONDUCT WATCHSTANDING EVALUATIONS OF OFFICERS.

NAVY PROTOTYPE STAFF PERSONNEL

THE SELECTION OF NAVAL OFFICERS FOR ASSIGNMENT TO THE PROTOTYPE STAFF IS MADE BY THE CHIEF OF NAVAL PERSONNEL WITH THE ASSISTANCE OF MY STAFF AT NAVAL REACTORS. BECAUSE OF THE OPERATIONAL NATURE OF THEIR ASSIGNMENT AT THE RROTOTYPE, HEAVY WEIGHT IN SELECTION IS GIVEN TO THE OFFICER'S PERFORMANCE IN THE FLEET. THE OFFICER SHOULD HAVE STOOD IN THE UPPER FIFTY PERCENT OF HIS NUCLEAR POWER SCHOOL AND PROTOTYPE CLASSES. AN EXCEPTION TO THIS IS SOMETIMES MADE BASED ON ABOVE AVERAGE PERFORMANCE IN ATTAINING ENGINEER OFFICER QUALIFICATION AS WELL AS OUTSTANDING FLEET PERFORMANCE. SIMILAR CRITERIA ARE APPLIED TO SELECTION OF ENLISTED STAFF INSTRUCTORS. WE ALSO PLACE HEAVY WEIGHT ON THEIR DEMONSTRATED PERFORMANCE ON A NUCLEAR SHIP.

INSTRUCTOR TRAINING

WE HAVE ESTABLISHED AN EXTENSIVE INSTRUCTOR TRAINING PROGRAM. EACH INSTRUCTOR FIRST COMPLETES WATCH QUALIFICATION THEN HE IS TRAINED AS AN INSTRUCTOR OVER A SIX WEEK PERIOD AFTER QUALIFICATION.

HE MUST SPECIFICALLY QUALIFY FOR EACH TYPE OF TRAINING HE WILL BE INVOLVED IN, WHETHER IT IS PRESENTING CLASSROOM LECTURES, CONDUCTING SYSTEMS CHECKOUTS, PROVIDING WATCHSTANDING TRAINING, OR PARTICIPATING AS AN ORAL BOARD MEMBER. THE RECORD OF HIS QUALIFICATION IS DOCUMENTED IN A QUALIFICATION STANDARD.

TO CONTROL QUALITY, THE STAFF PERSONEL ARE PERIODICALLY EVALUATED BY A TRAINING OFFICER OR A CONTRACTOR MANAGER.

THE BEST STAFF INSTRUCTORS ARE EVENTUALLY ASSIGNED AS CLASSROOM INSTRUCTORS. THEY QUALIFY BY GIVING "DRY RUN" LECTURES TO SENIOR PERSONNEL. THE FIRST TIME THEY GIVE THE CLASSROOM LECTURE, THEY ARE MONITORED 100% OF THE TIME AND ARE CRITIQUED BY SENIOR INSTRUCTORS OR MANAGEMENT PERSONNEL. THE CIVILIAN CONTRACTOR PERSONNEL WHO ARE INVOLVED IN THE OPERATION OF THE PLANT QUALIFY TO THE SAME STANDARDS AS OFFICERS. THEY ALSO MUST GO THROUGH A TRAINING PROGRAM IN ORDER TO BECOME INSTRUCTORS.

MONITORING AND AUDITS

AN EXTENSIVE AUDIT AND MONITORING PROGRAM HAS BEEN SET UP TO CONFIRM THAT THE PROGRAM IS RUN THE WAY THE GOVERNMENT AND THE CONTRACTOR WANT IT TO BE RUN.

THIS INVOLVES ROUTINE AND SPECIAL AUDITS BY CONTRACTOR MANAGEMENT, BY THE NAVAL REACTORS FIELD OFFICE, AND BY THE NAVY NUCLEAR POWER TRAINING UNIT. IN SOME CASES THE AUDITORS STAND WATCHES FOR EXPENDED PERIOD OF TIME IN-HULL OR IN TRAINING AREAS TO LEARN WHAT IS GOING ON IN DEPTH.

IN ADDITION, A SEPARATE GROUP OF SEA-EXPERIENCED NAVAL OFFICERS, CALLED THE PLANT PERFORMANCE EVALUATION ACTIVITY (PPEA), WHOSE DAILY JOB IS TO DO IN-DEPTH EVALUATIONS OF OPERATIONS AND TRAINING AT EACH PROTOTYPE.

FINALLY THERE ARE PERIODIC AUDITS BY THE CONTRACTOR LABORATORIES AND BY NAVAL REACTORS HEADQUARTERS PERSONNEL.

I REQUIRE MY NAVAL REACTORS FIELD OFFICE PERSONNEL, CERTAIN CIVILIAN CONTRACTOR MANAGERS, PLANT PERFORMANCE EVALUATION ACTIVITY PERSONNEL, AND THE SENIOR NAVAL OFFICER ASSIGNED TO THE PROTOTYPES TO WRITE ME WEEKLY AND ADVISE ME OF PROBLEMS THEY HAVE OBSERVED IN ANY AREA, AND WHAT CORRECTIVE ACTION IS BEING TAKEN. MANY OF THESE LETTERS ADDRESS TRAINING ISSUES AND PROVIDE ME A GOOD INSIGHT AS TO HOW TRAINING IS BEING CONDUCTED. MEMBERS OF MY STAFF AT NAVAL REACTORS IN WASHINGTON PERIODICALLY VISIT THE NUCLEAR POWER SCHOOL AND THE PROTOTYPES AND REPORT TO ME, IN WRITING, THEIR OBSERVATIONS IN ALL AREAS INCLUDING THE TRAINING PROGRAM.

THERE IS ASSIGNED, AT EACH NAVAL REACTORS FIELD OFFICE, A SEA-EXPERIENCED NUCLEAR TRAINED OFFICER WHOSE PRIMARY FUNCTION IS TO REVIEW ALL ASPECTS OF THE TRAINING PROGRAM AT THAT SITE. HE CONDUCTS FREQUENT AND DETAILED AUDITS. HE ALSO REPORTS IN WRITING TO ME EACH WEEK.

AS IS EVIDENCED FROM WHAT I HAVE SAID, DURING THE PERIODS OF FORMAL ACADEMIC INSTRUCTION AT NUCLEAR POWER SCHOOL AND PROTOTYPE TRAINING, A PROCESS OF WEEDING OUT THOSE PERSONNEL NOT SUITABLE TO BECOME NUCLEAR PLANT OPERATORS TAKES PLACE. ONLY THOSE OFFICERS AND ENLISTED MEN WHO HAVE DEMONSTRATED THAT THEY HAVE THE ACADEMIC AND PRACTICAL ABILITIES REQUIRED OF A SAFE AND COMPETENT OPERATOR ARE GRADUATED FROM THE TRAINING PROGRAM. I CONSIDER THIS PROCESS ESSENTIAL TO INSURE THAT ONLY THOSE WHO HAVE PROVED THEMSELVES TO BE SAFE AND COMPETENT OPERATORS ARE ASSIGNED TO NUCLEAR-POWERED SHIPS. IN THIS WAY I ATTEMPT TO MAINTAIN UNIFORM HIGH STANDARDS THROUGHOUT THE PROGRAM. YOU SHOULD NOTE THAT, EVEN WITH THE CAREFUL SELECTION OF PERSONNEL I HAVE DESCRIBED, AND A TRAINING PROGRAM THAT INVOLVES A SIGNIFICANT AMOUNT OF COUNSELING, THE ACADEMIC FAILURE RATE OVER THE ONE YEAR COURSE IS ABOUT TWELVE PER CENT FOR OFFICERS AND ABOUT TWENTY PER CENT FOR ENLISTED PERSONNEL.

ONCE THE OFFICER OR ENLISTED MAN HAS SATISFACTORILY COMPLETED NUCLEAR POWER SCHOOL AND PROTOTYPE TRAINING HE IS CONSIDERED TO BE "NUCLEAR QUALIFIED". IN THE CASE OF AN OFFICER, HE IS

ASSIGNED A NUCLEAR DESIGNATOR CODE WHICH IDENTIFIES HIM AS HAVING QUALIFIED FOR ASSIGNMENT TO JOBS INVOLVING THE SUPERVISION, OPERATION AND MAINTENANCE OF A NAVAL NUCLEAR PROPULSION PLANT. ENLISTED PERSONNEL RECEIVE A NAVY ENLISTED CLASSIFICATION CODE (NEC) WHICH LIKEWISE IDENTIFIES THE INDIVIDUAL AS BEING ASSIGNABLE TO A NUCLEAR BILLET. THESE DESIGNATOR CODES ARE IMMEDIATELY REMOVED IF THE INDIVIDUAL BECOMES UNASSIGNABLE TO A NUCLEAR JOB BECAUSE OF POOR PERFORMANCE, UNRELIABILITY, OR FOR OTHER CAUSES.

THESE NUCLEAR DESIGNATORS, BOTH FOR OFFICER AND ENLISTED PERSONNEL, ARE ASSIGNED BY THE CHIEF OF NAVAL PERSONNEL BASED ON NAVAL REACTORS RECOMMENDATION. REMOVAL OF AN OFFICERS NUCLEAR DESIGNATOR CAN ONLY BE DONE WITH MY APPROVAL. REMOVAL OF ENLISTED NUCLEAR DESIGNATION REQUIRES NAVAL REACTORS CONCURRENCE.

FLEET NUCLEAR PROPULSION PLANT TRAINING

ALL PERSONNEL WHO OPERATE ANY EQUIPMENT DIRECTLY ASSOCIATED WITH THE NUCLEAR PROPULSION PLANT ABOARD SHIP MUST HAVE RECEIVED THE ONE YEAR COURSE, INCLUDING THE FORMAL ACADEMIC TRAINING AND THE OPERATIONAL TRAINING AT ONE OF THE PROTOTYPES. THIS REQUIREMENT IS EXPLICITLY STATED IN THE NAVY'S INSTRUCTION ON OPERATION OF NUCLEAR-POWERED SHIPS. THIS STATES

THAT KEY PROPULSION PLANT WATCHES MAY BE STOOD ONLY BY GRADUATES OF THIS ONE YEAR COMBINED COURSE. THIS REQUIREMENT INSURES THAT ALL NUCLEAR PROPULSION PLANT OPERATORS HAVE RECEIVED TRAINING SUPERVISED BY THE DEPARTMENT OF ENERGY, AND ARE FAMILIAR WITH THE THEORETICAL AND PRACTICAL ASPECTS OF SAFE REACTOR OPERATION.

FOLLOWING COMPLETION OF TRAINING AT A PROTOTYPE, THE NEWLY QUALIFIED OFFICER OR ENLISTED PERSONNEL IS ASSIGNED TO BILLETS IN NUCLEAR-POWERED SHIPS. THEY THEN LEARN THE SYSTEMS AND PROCEDURES PERTAINING TO THEIR PARTICULAR SHIP. THE ENLISTED PERSONNEL COMPLETE QUALIFICATION ON ALL WATCH STATIONS PERTINENT TO THEIR RATING, AND THE OFFICERS QUALIFY AS ENGINEERING OFFICERS OF THE WATCH ON THE NUCLEAR PROPULSION PLANT OF THAT SHIP. THE QUALIFICATION PROGRAM IN EACH SHIP IS ACTUALLY A CONTINUOUS TRAINING AND RETRAINING PROCESS. I WILL NOW DESCRIBE HOW THIS FLEET NUCLEAR PROPULSION PLANT TRAINING IS CONDUCTED.

SHIPBOARD QUALIFICATION

OFFICER AND ENLISTED PERSONNEL REPORTING TO THE FLEET ARRIVE WITH A SOLID BACKGROUND IN THE PRINCIPLES OF OPERATION OF A NUCLEAR PROPULSION PLANT. THEY HAVE ALSO LEARNED "HOW TO QUALIFY." THE SHIPBOARD QUALIFICATION PROGRAM CONSISTS OF BASIC ENGINEERING QUALIFICATION (BEQ) AND INDIVIDUAL WATCHSTATION QUALIFICATION. BASIC ENGINEERING QUALIFICATION PROVIDES A CROSS

RATE BACKGROUND LEVEL OF KNOWLEDGE FOR ALL NUCLEAR TRAINED PERSONNEL, AND ALLOWS THE OPERATOR TO BUILD ON THE PRINCIPLES LEARNED AT THE NUCLEAR POWER SCHOOL AND THE PROTOTYPE. THIS QUALIFICATION CONSISTS OF VARIOUS NUCLEAR PROPULSION PLANT KNOWLEDGE REQUIREMENTS INCLUDING SUBJECTS SUCH AS REACTOR THEORY, SYSTEMS DESIGN, PRINCIPLES OF OPERATING AND CASUALTY PROCEDURES, ENGINEERING DEPARTMENT ORGANIZATION, RADIOLOGICAL CONTROLS AND CHEMISTRY. IN MOST CASES BEQ WILL BE PURSUED CONCURRENTLY WITH INITIAL WATCH QUALIFICATION AND SOME PORTIONS ARE PREREQUISITES FOR EACH WATCHSTATION. ADVANCED WATCH QUALIFICATIONS SUCH AS REACTOR OPERATOR REQUIRE COMPLETION OF BEQ IN ITS ENTIRETY.

THE SHIPBOARD PROGRAM OF WATCH QUALIFICATION FOR OFFICER AND ENLISTED PERSONNEL VARIES FROM THAT AT THE PROTOTYPE IN THAT IT IS LESS RIGIDLY STRUCTURED. THE INDIVIDUAL IS EXPECTED TO COMPLETE PRACTICAL FACTORS AND TRAINING WATCH REQUIREMENTS CONCURRENT WITH STUDY AND CHECKOUT ON SHIPBOARD PROPULSION PLANT SYSTEMS. SINCE HE HAS JUST COMPLETED PROTOTYPE QUALIFICATION THIS IS NOT AN UNREASONABLE EXPECTATION.

EACH OFFICER, UPON REPORTING TO HIS FIRST NUCLEAR SHIP, MUST QUALIFY AS ENGINEERING OFFICER OF THE WATCH (EOOW). HE COMPLETES BASIC ENGINEERING QUALIFICATION AND SELECTED THEORETICAL AND PRACTICAL PORTIONS OF ENLISTED WATCH STANDER

QUALIFICATION REQUIREMENTS AS PREREQUISITES TO THE ADVANCED REQUIREMENTS FOR EOOW. IT USUALLY TAKES THREE TO SIX MONTHS TO COMPLETE THIS QUALIFICATION DEPENDING ON THE ABILITY OF THE OFFICER, THE SHIP'S OPERATING SCHEDULE AND THE SIMILARITY OF THE SHIPBOARD PLANT WITH THAT OF THE PROTOTYPE THE OFFICER ATTENDED.

THE FIRST STEP IN SHIPBOARD QUALIFICATION FOR AN ENLISTED OPERATOR IS TO QUALIFY RAPIDLY ON AN IN-RATE WATCHSTATION SO THAT HE MAY BECOME A USEFUL MEMBER OF THE CREW. THE LENGTH OF TIME REQUIRED WILL VARY DEPENDING ON THE WATCHSTATION, AND THE ADDITIONAL FACTORS PREVIOUSLY MENTIONED AS AFFECTING OFFICER QUALIFICATION RATE. FOR EXAMPLE, AN ENGINEERING LABORATORY TECHNICIAN (ELT) MAY BE ABLE TO QUALIFY AS A SHIPBOARD ELT IN ONLY A FEW DAYS BECAUSE SHIPBOARD RADIOLOGICAL CONTROLS AND CHEMISTRY EQUIPMENT, PROCEDURES, AND ASSOCIATED SYSTEMS ARE VERY SIMILAR TO THOSE AT ALL PROTOTYPES. BUT IT WILL USUALLY TAKE SEVERAL WEEKS OR MONTHS FOR HIM TO QUALIFY AT OTHER WATCHSTATIONS.

THE SUBMARINE AND SURFACE SHIP FORCE COMMANDERS HAVE PROMULGATED RECOMMENDED QUALIFICATION PATHS FOR EACH RATE AND HAVE PROVIDED GUIDELINES INDICATING THE APPROXIMATE LENGTH OF TIME THE AVERAGE INDIVIDUAL IS EXPECTED TO COMPLETE EACH WATCH QUALIFICATION. EXPERIENCE HAS SHOWN THAT MANY OPERATORS WILL QUALIFY IN LESS TIME THAN THE GUIDELINE PERIOD WHILE A

FEW WILL EXCEED IT. ULTIMATELY EACH ENLISTED MAN IS REQUIRED TO QUALIFY ON HIS MOST ADVANCED IN-RATE WATCHSTATION AND, UPON GAINING APPROPRIATE SENIORITY AND EXPERIENCE, TO QUALIFY AS ENGINEERING WATCH SUPERVISOR (EWS), THE MOST SENIOR ENLISTED WATCH.

PREVIOUSLY QUALIFIED PERSONNEL, OFFICER AND ENLISTED, RETURNING FROM SHORE DUTY OR TRANSFERRING FROM ANOTHER SHIP WILL BE EXAMINED ON THE SENIOR WATCHSTATION ON WHICH THEY WERE PREVIOUSLY QUALIFIED. THE RESULTS OF THIS EXAMINATION WILL DETERMINE THE TYPE AND LENGTH OF QUALIFICATION REQUIRED FOR REQUALIFICATION IN THEIR NEW SHIP.

THE MECHANICS OF SHIPBOARD WATCH QUALIFICATION ARE SIMILAR TO THOSE ALREADY DESCRIBED AND IN USE AT THE PROTOTYPES. THE OPERATOR MUST STUDY THE SYSTEM OR OTHER SUBJECT, PHYSICALLY TRACE OUT THE SYSTEM, LOCATE COMPONENTS AND, FINALLY, RECEIVE A CHECKOUT WITH SATISFACTORY KNOWLEDGE LEVEL INDICATED BY A SIGNATURE ON HIS QUALIFICATION CARD WHICH IS SIMILAR IN PURPOSE TO THE PROTOTYPE QUALIFICATION STANDARD. HE MUST COMPLETE PRACTICAL FACTORS AND DEMONSTRATE SATISFACTORY ABILITY TO HANDLE HIS WATCHSTATION DURING TRAINING WATCHES. FINAL COMPREHENSIVE ORAL AND WRITTEN EXAMINATIONS COMPLETE THIS QUALIFICATION PROCESS.

QUALIFICATION QUALITY CONTROL

TO ASSURE SAFE AND RELIABLE PROPULSION PLANT OPERATION, I HAVE, THROUGH THE CHIEF OF NAVAL OPERATIONS, ESTABLISHED HIGH STANDARDS AND REQUIRE THAT THESE STANDARDS BE MAINTAINED WITHIN THE SHIPBOARD QUALIFICATION PROGRAM. THE STANDARDS THAT ARE TO BE OBSERVED ARE SPELLED OUT IN THE ENGINEERING DEPARTMENT MANUAL FOR NAVAL NUCLEAR PROPULSION PLANTS, AND IN QUALIFICATION GUIDES FOR NUCLEAR PROPULSION PLANT WATCHSTANDERS. THESE PUBLICATIONS ARE PREPARED BY NAVAL REACTORS AND FORM THE BASIS FOR DEVELOPMENT OF SHIPBOARD QUALIFICATION REQUIREMENTS. QUALITY CONTROL OF THE QUALIFICATION PROGRAM IS MAINTAINED BY FORMALLY STATED REQUIREMENTS. PERSONNEL WHO ARE AUTHORIZED TO CERTIFY COMPLETION OF THE VARIOUS QUALIFICATION REQUIREMENTS ARE DESIGNATED IN WRITING AND MUST DEMONSTRATE THAT THEY POSSESS THE REQUISITE KNOWLEDGE LEVEL TO BE A QUALIFICATION PETTY OFFICER. THE ENGINEERING DEPARTMENT MANUAL DEFINES WHO MAY APPROVE THE WRITTEN EXAMINATIONS TO BE GIVEN FOR EACH WATCHSTATION AND ALSO SPECIFIES WHO HAS THE AUTHORITY TO CERTIFY FINAL QUALIFICATION. FOR EXAMPLE, THE COMMANDING OFFICER IS PERSONALLY REQUIRED TO CERTIFY THE FINAL QUALIFICATION OF ALL REACTOR OPERATORS, AS WELL AS CERTAIN OTHER WATCHSTANDERS. THE END PRODUCT OF THE SYSTEM I HAVE DESCRIBED IS A TRAINED NUCLEAR PROPULSION PLANT WATCHSTANDER WHO UNDERSTANDS HOW THE PLANT WORKS, WHY IT WORKS AND WHAT IS REQUIRED FOR SAFE OPERATION

CONTINUING TRAINING PROGRAM

SHIPBOARD NUCLEAR PROPULSION PLANT TRAINING IS NOT LIMITED TO THE WATCH QUALIFICATION PROGRAM. A CONTINUOUS SHIPBOARD TRAINING PROGRAM IS A HIGH PRIORITY PROGRAM CONSISTING OF MAINTENANCE OF WATCHSTANDING PROFICIENCY, WATCHSTANDER REQUALIFICATION, AND WHAT I WILL CALL "RECURRING TRAINING."

MAINTENANCE OF WATCHSTANDING PROFICIENCY

AN OPERATOR CAN BE CONSIDERED PROFICIENT ON A GIVEN WATCHSTATION ONLY IF HE STANDS WATCH AT A PRESCRIBED FREQUENCY ON THAT WATCHSTATION. IN THE NAVAL NUCLEAR PROGRAM WE DEFINE THIS REQUIREMENT AND MAINTAIN RECORDS SO THAT WE CAN BE SURE WHEN WE ASSIGN AN OPERATOR TO A WATCH STATION THAT HE HAS "MAINTAINED HIS PROFICIENCY" ON THAT WATCHSTATION. FOR EXAMPLE, I REQUIRE AN ENGINEERING OFFICER OF THE WATCH TO STAND AT LEAST TWO-FOUR HOUR WATCHES EACH MONTH TO MAINTAIN PROFICIENCY. IF A WATCHSTANDER DOES NOT MEET THESE REQUIREMENTS HIS NAME IS REMOVED FROM THE LIST OF QUALIFIED WATCHSTANDERS AND HE IS REQUIRED TO COMPLETE SPECIAL TRAINING SPECIFIED BY THE SHIP'S ENGINEER OFFICER BEFORE HE CAN BE RETURNED TO THE LIST OF QUALIFIED WATCHSTANDERS.

WATCHSTANDER REQUALIFICATION PROGRAM

THE WATCHSTANDER REQUALIFICATION PROGRAM TAKES INTO ACCOUNT: (1) THE OPERATOR WHO HAS FAILED TO MAINTAIN OR RE-ESTABLISH WATCHSTANDING PROFICIENCY FOR MORE THAN SIX MONTHS,

(2) THE NEED TO PERIODICALLY REESTABLISH A MINIMUM LEVEL OF WATCHSTANDER KNOWLEDGE SINCE, REGARDLESS OF HOW OFTEN THE OPERATOR STANDS WATCH, HIS KNOWLEDGE LEVEL DEGRADES WITH TIME AND (3) THE NEED TO REQUALIFY PERSONNEL WHEN NEW EQUIPMENT IS ADDED OR ALTERATIONS MADE TO INSTALLED EQUIPMENT. THIS PROGRAM REQUIRES THE COMPLETE REQUALIFICATION OF ANY WATCH-STANDER WHO HAS NOT STOOD A PARTICULAR WATCH FOR OVER SIX MONTHS. IT REQUIRES THE COMPLETE REQUALIFICATION OF ALL WATCHSTANDERS EVERY TWO YEARS REGARDLESS OF HOW OFTEN THEY STAND WATCH.

WHEN NEW EQUIPMENT IS ADDED, OR INSTALLED EQUIPMENT ALTERED, THE COMMANDING OFFICER AND ENGINEER OFFICER DETERMINE TO WHAT EXTENT REQUALIFICATION IS REQUIRED. ALL WATCHSTANDERS ARE ALSO REQUIRED TO REQUALIFY ON SHIPS UNDERGOING OVERHAUL. THIS PROVISION ENSURES THAT WATCHSTANDERS WHO MAY NOT HAVE STOOD A WATCH ON AN OPERATING PROPULSION PLANT FOR SEVERAL MONTHS OR A LONGER PERIOD ARE REQUALIFIED ON THOSE WATCHSTATIONS BEFORE THE PLANT IS AGAIN OPERATED. THIS NOT ONLY UPGRADES WATCHSTANDING BUT ENSURES ADEQUACY OF TRAINING ON EQUIPMENT NEW TO THE WATCHSTANDER.

RECURRING TRAINING

A MAJOR PORTION OF TRAINING TIME IS SPENT ON "RECURRING TRAINING". THERE IS A CONTINUING NEED TO REINFORCE INITIAL TRAINING AND PROVIDE TRAINING WHICH INCREASES THE LEVEL OF KNOWLEDGE OF ALL NUCLEAR OPERATORS. I WANT TO MAKE IT CLEAR THAT, IN ORDER TO MAINTAIN HIGH STANDARDS IN THE NAVY NUCLEAR PROPULSION PROGRAM, SHIPS COMMANDING OFFICERS MUST CONDUCT RECURRING TRAINING. THIS TRAINING IS ALSO A VEHICLE FOR IMPROVING THE WATCHSTANDER'S ABILITY TO HANDLE CASUALTIES, AND SUPPORTS MORE ADVANCED WATCH QUALIFICATION.

THE METHODS USED IN CONDUCTING NUCLEAR PROPULSION PLANT RECURRING TRAINING IN SHIPS ARE THE SAME PROVEN WAYS OF ACCOMPLISHING TRAINING I HAVE DESCRIBED AND ARE IN USE AT NUCLEAR POWER SCHOOL AND PROTOTYPES. LECTURES AND SEMINARS ARE CONDUCTED ON A DEPARTMENTAL AND DIVISIONAL BASIS. IN MOST CASES A MONITOR. SENIOR TO THE INSTRUCTOR OR SEMINAR LEADER IS PRESENT TO ASSIST IN KEEPING THE TRAINING SESSION "ON TRACK", AND TO PROVIDE FEEDBACK TO THE COMMAND AND THE INSTRUCTOR ON THE QUALITY OF THE LECTURE OR SEMINAR. LECTURES ARE GIVEN BY EXPERIENCED PERSONNEL WHO ARE SPECIFICALLY SELECTED TO FIT THE TOPIC AND AUDIENCE. SELECTION OF INSTRUCTORS, LECTURERS AND MONITORS IS AN IMPORTANT QUALITY CONTROL MEASURE.

A COMPREHENSIVE EXAMINATION PROGRAM IS A KEY FACTOR IN ANY FORMAL TRAINING PROGRAM. EXAMINATIONS ARE NECESSARY TO ENSURE

UNDERSTANDING AND RETENTION OF THE MATERIAL COVERED IN LECTURES AND SEMINARS. THEREFORE, EXAMINATIONS ARE GIVEN COVERING MOST "RECURRING TRAINING" SESSIONS AND ARE DESIGNED TO BE TOUGH ENOUGH TO CHALLENGE THE MOST KNOWLEDGEABLE CREW MEMBERS.

CASUALTY DRILL TRAINING

IN ADDITION TO CLASSROOM TYPE TRAINING, THE RECURRING TRAINING PROGRAM IS ALSO COMPOSED OF PRACTICAL EVOLUTIONS AND CASUALTY DRILLS. THESE FORM AN IMPORTANT PART OF THE SHIPBOARD TRAINING PLAN, ALLOWING THE NUCLEAR PROPULSION PLANT OPERATOR TO BUILD ON HIS THEORETICAL KNOWLEDGE OF THE PROPULSION PLANT AND PUT INTO PRACTICE THE PRINCIPLES OF OPERATING AND CASUALTY PROCEDURES HE HAS STUDIED. THE ENGINEERING DEPARTMENT MANUAL FOR NAVAL NUCLEAR PROPULSION PLANTS LISTS THE REQUIRED DRILLS AND EVOLUTIONS AND INDICATES WHETHER THE DRILL SHOULD BE WALKED-THROUGH OR ACTUALLY CONDUCTED. IN SOME CASES, PART OF THE CASUALTY ACTION MAY BE WALKED-THROUGH AND PART ACTUALLY CARRIED OUT. WITHIN THE CONSTRAINTS OF REACTOR AND SHIP SAFETY, A CONSCIOUS EFFORT IS MADE TO CARRY OUT THESE CASUALTY DRILLS IN A REALISTIC MANNER.

POORLY CONDUCTED CASUALTY DRILL TRAINING, WHICH ALLOWS IMPROPER ACTIONS TO OCCUR WITHOUT IDENTIFICATION AND CORRECTION, SIMPLY REINFORCES THE WRONG WAY TO DO THINGS IN THE PROPULSION PLANT. IN EFFECT, WE COULD TRAIN OURSELVES TO OPERATE THE PLANT IN AN UNSATISFACTORY FASHION. TO AVOID THIS I INSIST THAT CASUALTY DRILLS BE CAREFULLY PLANNED, CLOSELY MONITORED AND

THOROUGHLY CRITIQUED.

I WILL DESCRIBE SOME OF THE CONSIDERATIONS THAT ARE INVOLVED IN THE CONDUCT OF CASUALTY DRILLS ON A NUCLEAR SHIP. FIRST, A DRILL GUIDE IS PREPARED WHICH DESCRIBES THE DRILL, HOW IT WILL BE INITIATED, WHAT IS TO BE ACCOMPLISHED, SPECIFIES SAFETY MONITORS AND OBSERVERS, ETC. VARIOUS PROPULSION PLANT REFERENCE MATERIAL AND THE ENGINEERING DEPARTMENT MANUAL ARE USED. THE ENGINEER OFFICER THEN SUBMITS THIS DRILL GUIDE TO THE SHIP'S COMMANDING OFFICER FOR HIS APPROVAL. A FILE OF THESE APPROVED DRILL GUIDES IS MAINTAINED FOR RECURRING USE. THE COMMANDING OFFICER MUST APPROVE THE ACTUAL CONDUCT OF EACH DRILL EVEN THOUGH HE HAS PREVIOUSLY APPROVED THE BASIC DRILL GUIDE. SOMETIMES THE WATCH SECTION SCHEDULED FOR A PARTICULAR DRILL WILL BE NOTIFIED WELL IN ADVANCE OF THE NATURE OF THE DRILL IN ORDER THAT SPECIFIC TRAINING, SUCH AS A REVIEW OF THE APPROPRIATE CASUALTY PROCEDURES, MAY BE ACCOMPLISHED. THIS MAY BE APPROPRIATE WHERE THE SECTION WILL BE DOING A DIFFICULT DRILL FOR THE FIRST TIME OR WHERE THE SHIP HAS JUST COMPLETED A LENGTHLY PERIOD WITH THE PLANT SHUTDOWN.

DRILL MONITORS AND SAFETY OBSERVERS MUST BE FULLY AWARE OF WHAT IS EXPECTED OF THEM AND THE LIMITS TO THEIR RESPONSIBILITIES. THIS IS ACCOMPLISHED AT A BRIEFING ATTENDED BY ALL MONITORS AND SAFETY OBSERVERS AND NORMALLY LED BY THE ENGINEERING OFFICER. I CONSIDER IT APPROPRIATE THAT THE SHIP'S COMMANDING OFFICER OR EXECUTIVE OFFICER BE PRESENT AT THESE

BRIEFINGS TO THE MAXIMUM EXTENT POSSIBLE. AN IMPORTANT ASPECT OF THIS SESSION IS TO REVIEW IN DETAIL HOW THE DRILL WILL BE INITIATED AND HOW THE SYMPTOMS OF THE CASUALTY WILL BE MADE KNOWN TO THE WATCHSTANDERS IN CASES WHERE THE ENTIRE CASUALTY CANNOT BE ALLOWED TO OCCUR BECAUSE OF REACTOR OR SHIP SAFETY. REALISM IN THE CONDUCT OF CASUALTY DRILLS IS IMPORTANT, BUT SAFETY CONSIDERATIONS DICTATE THAT SOME CASUALTIES SHOULD NOT ACTUALLY BE DONE FOR TRAINING. THEREFORE, WE USE TECHNIQUES FOR PRESENTING THE SYMPTOMS OF THESE CASUALTIES IN A MANNER THAT WILL, AS NEARLY AS PRACTICABLE, APPEAL TO THE SAME SENSES THAT THE WATCHSTANDER WOULD NORMALLY USE IN THE CASUALTY SITUATION. DURING THIS PRE-DRILL BRIEFING THE APPLICABLE CASUALTY PROCEDURES ARE ALSO REVIEWED TO ENSURE THAT ALL MONITORS AND SAFETY OBSERVERS KNOW THE CORRECT WATCHSTANDER ACTIONS.

THE ACTUAL CASUALTY DRILL MAY BE PRE-ANNOUNCED OR MAY BE A SURPRISE TO THE WATCH SECTION. THE ENGINEER OFFICER WILL NORMALLY MAKE THIS DETERMINATION. SOME COMBINATION OF BOTH METHODS IS APPROPRIATE TO ENSURE THAT THE WATCHSTANDERS CAN PROPERLY-HANDLE UNEXPECTED PLANT CASUALTIES. DURING DRILLS, MONITORS CORRECT WATCHSTANDER ERRORS ON THE SPOT, WHERE FAILURE TO DO SO WOULD REINFORCE IMPROPER ACTIONS. SAFETY MONITORS ARE STATIONED TO PREVENT INCORRECT WATCHSTANDER ACTION WHICH COULD HAZARD THE REACTOR PLANT. DRILLS ARE ALLOWED TO PROGRESS LONG ENOUGH TO EVALUATE THE SECTION'S ABILITY TO RESTORE THE PLANT TO ITS NORMAL CONDITION. OBVIOUSLY THERE ARE PRACTICAL LIMITS TO DRILL LENGTH AND IN SOME CASES THE FIRST WATCH SECTION WILL

CARRY OUT THE INITIAL CASUALTY ACTIONS AND A SECOND SECTION WILL RECOVER THE PLANT BACK TO A NORMAL CONDITION. UPON COMPLETION OF THE DRILL, A CRITIQUE INVOLVING ALL DRILL MONITORS IS IMMEDIATELY HELD TO COLLECT COMMENTS, DETERMINE WHERE ERRORS WERE MADE AND EVALUATE THE OVERALL CONDUCT OF THE DRILL. APPROPRIATE REFERENCE MATERIAL SUCH AS THE OPERATING MANUALS FOR THE SHIPS PROPULSION PLANT ARE ESSENTIAL AT THIS SESSION TO ACCURATELY ASSESS ALL OF THE CASUALTY ACTIONS TAKEN.

AFTER THE ENGINEER OFFICER HAS ASSEMBLED THE SIGNIFICANT COMMENTS FROM THE MONITOR CRITIQUE HE CONDUCTS A CRITIQUE OF THE DRILL FOR THE WATCH SECTION AFTER THEY COME OFF WATCH. IF TRAINING LESSONS ARE TO BE LEARNED THAT WOULD BENEFIT OTHER ENGINEERING DEPARTMENT PERSONNEL, THE ENGINEER OFFICER WILL CAUSE THIS INFORMATION TO BE DISSEMINATED. FINALLY, WHERE DRILL DEFICIENCIES SHOW WEAKNESSES IN THE SHIP'S FUNDAMENTAL TRAINING PROGRAM, CORRECTIVE MEASURES ARE TAKEN TO UPGRADE THESE AREAS. SIMILIAR REQUIREMENTS FOR MAINTAINING WATCHSTANDING PROFICIENCY AND CONDUCTING CONTINUING TRAINING ARE ALSO ESTABLISHED AT THE PROTOTYPE PLANTS FOR STAFF PERSONNEL.

TRAINING FOR NEW CONSTRUCTION NUCLEAR-POWERED SHIPS

TRAINING OF PERSONNEL ASSIGNED TO A NEW CONSTRUCTION NUCLEAR-POWERED SHIP BEGINS UPON ARRIVAL OF THE CREW AT THE SHIPYARD. THIS ARIVAL IS TIMED SO THAT THE MAJORITY OF THE ENGINEERING DEPARTMENT PERSONNEL ARE PRESENT FOR THE ENTIRE PROPULSION

PLANT TEST PROGRAM. TWO-THIRDS OF THE NUCLEAR-TRAINED PERSONNEL FOR THE NEW CREW ARE REQUIRED TO HAVE SERVED ON AN OPERATING NUCLEAR-POWERED SHIP AND BE QUALIFIED ON THE PROPULSION PLANT OF THAT SHIP. ENGINEERING PERSONNEL RECEIVE CLASSROOM LECTURES CONDUCTED BY THE EXPERIENCED SHIP'S ENGINEERING PERSONNEL, SHIPYARD PERSONNEL, AND MANUFACTURERS' REPRESENTATIVES. ALL PERSONNEL MUST COMPLETE INITIAL SHIPBOARD WATCHSTANDER QUALIFICATION OR REQUALIFY UNDER PROCEDURES SIMILAR TO THOSE FOR INITIAL QUALIFICATION, IN THE CASE OF OPERATORS WHO HAVE PREVIOUSLY QUALIFIED IN ANOTHER SHIP. THE CREW GAINS PRACTICAL OPERATING EXPERIENCE ABOARD SHIP BY PARTICIPATING DIRECTLY IN THE TESTING OF THE PROPULSION PLANT, BEGINNING WITH EXTENSIVE TESTS BEFORE THE REACTOR CORE IS INSTALLED. IN THE CASE OF CERTAIN NEW DESIGN SHIPS, SPECIAL SHORT COURSES FOR THE NEW CONSTRUCTION NUCLEUS CREWS ARE TAUGHT AT THE PROTOTYPE PLANT OR THE APPROPRIATE NAVAL REACTORS LABORATORY. THIS BETTER PREPARES THE NUCLEAR TRAINED PERSONNEL FOR OPERATION OF THE PROPULSION PLANT DURING THE INITIAL TEST PROGRAM. THE SHIP'S CREW OPERATES THE EQUIPMENT DURING THE TEST PROGRAM, UNDER THE SURVEILLANCE OF QUALIFIED ENGINEERS AND SCIENTISTS INCLUDING REPRESENTATIVES OF THE DEPARTMENT OF ENERGY. IN THIS WAY THE CREW BECOMES THOROUGHLY FAMILIAR WITH OPERATION AND MAINTENANCE OF THE PROPULSION PLANT, AND IS READY TO TAKE THE SHIP TO SEA ON ITS FIRST TRIALS WITH MAXIMUM ASSURANCE OF SAFE OPERATION.

TRAINING FOR NUCLEAR POWERED SHIPS UNDERGOING OVERHAUL

TRAINING OF NUCLEAR PROPULSION PLANT OPERATORS ON SHIPS UNDERGOING OVERHAUL IS ACCOMPLISHED USING THE SAME METHODS AS FOR OPERATING SHIPS. THERE ARE SOME MINOR DIFFERENCES IN THAT THERE IS LESS OPPORTUNITY FOR PRACTICAL TRAINING, AND SOME SPECIAL TRAINING SESSIONS MAY BE CONDUCTED BY CONTRACTOR OR SHIPYARD PERSONNEL. AS I HAVE MENTIONED, ALL WATCHSTANDERS MUST REQUALIFY UNDER PROCEDURES SIMILAR TO THOSE FOR INITIAL QUALIFICATION.

ENGINEER OFFICER TRAINING AND QUALIFICATION

IN ADDITION TO THE ONE YEAR COURSE OF INSTRUCTION AND SUBSEQUENT SHIPBOARD QUALIFICATION ALREADY DESCRIBED, THOSE OFFICERS WHO ARE ASSIGNED AS ENGINEER OFFICER OF NUCLEAR-POWERED SHIPS ARE FORMALLY EXAMINED AND QUALIFIED. EACH NUCLEAR TRAINED JUNIOR OFFICER IS EXPECTED TO COMPLETE THIS QUALIFICATION PRIOR TO THE END OF HIS FIRST OR, IN THE CASE OF SURFACE SHIP OFFICERS, SECOND SHIPBOARD TOUR OF DUTY. THIS PROGRAM INVOLVES PREPARATION BY THE CANDIDATE, ON BOARD HIS SHIP, AND FINAL APPROVAL BY ME AFTER HE SUCCESSFULLY COMPLETES A COMPREHENSIVE WRITTEN AND ORAL EXAMINATION ADMINISTERED OVER A TWO DAY PERIOD AT NAVAL REACTORS IN WASHINGTON.

THE TRAINING PROGRAM FOR THE PROSPECTIVE ENGINEER OFFICER IS AN INDIVIDUALLY ESTABLISHED STUDY PLAN FORMULATED UNDER THE SUPERVISION OF HIS COMMANDING OFFICER. FROM THE PRACTICAL

EXPERIENCE STANDPOINT THE CANDIDATE MUST HAVE TWO YEARS EXPERIENCE ONBOARD A NUCLEAR SHIP AND MUST HAVE BEEN AN ENGINEERING DEPARTMENT DIVISION OFFICER FOR AT LEAST ONE YEAR. HE MUST, OF COURSE, HAVE THE RECOMMENDATION OF HIS COMMANDING OFFICER. WHEN SO RECOMMENDED, THE CANDIDATE WILL BE ORDERED BY THE CHIEF OF NAVAL PERSONNEL TO REPORT TO NAVAL REACTORS FOR TWO DAYS TO BE EXAMINED FOR QUALIFICATION AS ENGINEER OFFICER. THE FIRST DAY THE OFFICER WILL TAKE A SEVEN AND ONE-HALF HOUR WRITTEN EXAMINATION CONSISTING OF FIVE SECTIONS COVERING REACTOR THEORY, RADIOLOGICAL CONTROLS AND CHEMISTRY, FLUID SYSTEMS, ELECTRICAL SYSTEMS AND OVERALL PLANT OPERATIONS. HE MUST PASS ALL SECTIONS OF THE EXAMINATION. ON THE SECOND DAY THE CANDIDATE RECEIVES THREE ORAL INTERVIEWS ON PROPULSION PLANT SUBJECTS. HE MUST PASS ALL THREE ORAL INTERVIEWS. IF HE SUCCESSFULLY PASSES ALL AREAS OF THE EXAMINATION HE WILL THEN BE DESIGNATED AS QUALIFIED TO SERVE AS ENGINEER OFFICER OF A NUCLEAR SHIP. IF HE FAILS EITHER THE WRITTEN OR ORAL EXAMINATION, ONE REEXAMINATION IS USUALLY ALLOWED. THE OFFICER IS REQUIRED TO COMPLETE BOTH AN ORAL AND WRITTEN REEXAMIANTION IN ALL AREAS REGARDLESS OF THE AREA OR AREAS HE FAILED. BEING SUCCESSFUL IN ATTAINING THE ENGINEER OFFICER QUALIFICATION DOES NOT GUARANTEE THAT THE INDIVIDUAL WILL SERVE AS ENGINEER OFFICER SINCE ONLY THE TECHNICALLY BEST PEOPLE ARE CHOSEN FOR THIS ASSIGNMENT. ALL OFFICERS NOW ASSIGNED AS ENGINEER OFFICER HAVE BEEN QUALIFIED UNDER THIS SYSTEM. WE HAVE ALSO REACHED THE POINT WHERE ALL NUCLEAR-TRAINED OFFICERS MUST PASS THIS ADDITIONAL QUALIFICATION REQUIREMENT IN ORDER TO BE ASSIGNED AS EXECUTIVE OFFICER AND COMMANDING OFFICER OF A NUCLEAR-POWERED SHIP.

COMMANDING OFFICER TRAINING AND QUALIFICATION

CLEARLY, THE ONE PERSON HAVING THE GREATEST OVERALL RESPONSIBILITY FOR THE SAFE OPERATION OF THE NUCLEAR PROPULSION PLANT IS THE SHIP'S COMMANDING OFFICER. THEREFORE, IT SHOULD NOT BE SURPRISING THAT EACH PROSPECTIVE COMMANDING OFFICER IS REQUIRED TO ATTEND A COURSE OF INSTRUCTION AT NAVAL REACTORS AND SATISFACTORILY COMPLETE THIS COURSE PRIOR TO REPORTING TO A SHIP AS COMMANDING OFFICER.

IN THE EARLY YEARS OF THE PROGRAM, SENIOR SEA-EXPERIENCED OFFICERS WERE SELECTED AS COMMANDING OFFICERS OF THE FIRST NUCLEAR-POWERED SHIPS. THESE PROSPECTIVE COMMANDING OFFICERS RECEIVED THE SAME TYPE OF TRAINING THAT OTHER OFFICERS IN NUCLEAR SHIPS RECEIVED. HOWEVER, THE ACADEMIC INSTRUCTION WAS GIVEN BY MEMBERS ON THE NAVAL REACTORS STAFF AT HEADQUARTERS IN WASHINGTON. IN ADDITION TO FORMAL CLASSROOM TRAINING, THE PROSPECTIVE COMMANDING OFFICERS RECEIVED ADDED MATERIAL ON THOSE SUBJECTS AFFECTING THE TESTING AND OPERATION OF NUCLEAR-POWERED SHIPS WHICH THEY NEEDED TO KNOW BY REASON OF THEIR RESPONSIBILITIES AS COMMANDING OFFICERS. OPERATIONAL TRAINING OF PROSPECTIVE COMMANDING OFFICERS CONSISTED OF APPROXIMATELY EIGHT WEEKS OF CONCENTRATED INSTRUCTION AND QUALIFICATION ON ALL ENGINEERING WATCH STATIONS AT ONE OF THE NAVAL REACTORS PROTOTYPES. THEY WERE ALSO REQUIRED TO PASS ORAL AND WRITTEN EXAMINATIONS BOTH AT THE PROTOTYPES AND THE NAVAL REACTORS HEADQUARTERS.

Since 1961, prospective commanding officers of all nuclear-powered submarines have had previous duty on board a nuclear-powered ship, and have therefore undergone training at one of the Naval Nuclear Power Schools and at a prototype upon initial entry into the nuclear power program. Upon selection as a Commanding Officer, the prospective commanding officer reports to Naval Reactors for a thirteen week course. This course is a concentrated training period covering the nuclear propulsion plant of the ship to which the officer is scheduled for assignment as Commanding Officer. Subjects covered include mechanical, fluid and electrical (including control and instrumentation) systems, plant materials, reactor engineering, reactor theory, reactor safety and chemistry and radiological controls. The Prospective Commanding Officer is examined in all areas and must pass each one. Two oral examinations are also given covering course material. A final comprehensive written examination of similar length and composition to the Prospective Engineer Officer examination is administered, and the Prospective Commanding Officer must pass all sections of this examination. In addition, a final oral examination on reactor safety is given by a four member Naval Reactors board. Special briefings by senior naval officers and training in subjects that will aid the Prospective Commanding Officer in running his ship are included in addition to the technical training.

I approve satisfactory course completion for each Prospective Commanding Officer before he can actually go on to command a nuclear ship.

OTHER NAVAL REACTORS SPONSORED TRAINING

I HAVE DIRECTED THAT CERTAIN OTHER TRAINING BE CONDUCTED WHEN IT IS REQUIRED TO MEET AN IDENTIFIED SPECIFIC NEED. FOR EXAMPLE, TWO YEARS AGO IT CAME TO MY ATTENTION THAT ELECTRONICS TECHNICIANS WERE SEVERELY LACKING IN THE KNOWLEDGE AND SKILLS TO PROPERLY CONDUCT MAINTENANCE ON THE ELECTRONIC EQUIPMENT ASSOCIATED WITH THE NUCLEAR PROPULSION PLANT. I DIRECTED THE ESTABLISHMENT OF A FIVE WEEK COURSE AT THE PROTOTYPE SITES IN IDAHO AND NEW YORK TO TEACH THE NECESSARY ELECTRONICS REPAIR TECHNIQUES.

AS I HAVE METIONED, SPECIAL DESIGN COURSES ARE TAUGHT FOR THE NUCLEUS CREWS OF SOME NEW DESIGN SHIPS. FOR EXAMPLE, WE TEACH A SEVEN WEEK DESIGN COURSE AT WEST MILTON, NEW YORK FOR THE NUCLEAR TRAINED CREW MEMBERS OF TRIDENT SUBMARINES.

AIRCRAFT CARRIER PROSPECTIVE EXECUTIVE OFFICERS AND REACTOR OFFICERS ARE REQUIRED TO ATTEND THE PROSPECTIVE COMMANDING OFFICERS COURSE AT NAVAL REACTORS, AND CERTAIN FORCE COMMANDER STAFF PERSONNEL ATTEND THE CHEMISTRY AND RADIOLOGICAL CONTROLS SECTION OF THAT COURSE. IN ADDITION, MEMBERS OF MY STAFF AT THE VARIOUS FIELD OFFICES WHO MONITOR PROTOTYPE, SHIPYARD AND SHIP PERFORMANCE ARE REQUIRED TO DEMONSTRATE BY EXAMINATION THAT THEY HAVE AN ADEQUATE LEVEL OF KNOWLEDGE TO PERFORM THOSE DUTIES.

QUALITY CONTROL AND FEEDBACK TO TRAINING

THROUGHOUT MY COMMENTS, I HAVE INDICATED VARIOUS POINTS WHERE A MEASURE OF QUALITY CONTROL IS EXERCISED IN THE TRAINING PROGRAM. I WILL NOW REVIEW AND FURTHER DISCUSS THE KEY MEANS BY WHICH WE CONTROL THE STANDARDS OF OUR SHIPBOARD TRAINING. MONITORS ARE USED BOTH IN THE LECTURE AND SEMINAR AREA AND IN CASUALTY DRILLS. OFFICER AND ENLISTED PERSONNEL ARE USED AS MONITORS, WITH THE PRINCIPAL CRITERIA FOR SELECTION BEING THE INDIVIDUALS'S KNOWLEDGE OF THE AREA HE IS TO MONITOR. FREQUENT EXAMINATIONS ARE USED, NOT JUST TO CONFIRM AN ADEQUATE LEVEL OF KNOWLEDGE BUT TO INCREASE KNOWLEDGE AS WELL. THE NUCLEAR TRAINED PERSONNEL ON THE STAFFS OF THE SHIP'S IMMEDIATE SUPERIORS IN THE CHAIN OF COMMAND (FOR EXAMPLE, SQUADRON OR FORCE COMMANDER) ROUTINELY REVIEW SHIPBOARD TRAINING FOR ITS EFFECTIVENESS. OFTEN THIS REQUIRES THAT STAFF PERSONNEL GO TO SEA AND ACTUALLY OBSERVE THE TRAINING BEING CONDUCTED. THE PRE-CRITICALITY REACTOR SAFEGUARDS EXAMINATION CONDUCTED BY MY STAFF ON SHIPS WITH NEW REACTOR CORES PROVIDE A DIRECT EVALUATION OF THE STATE OF THE CREWS TRAINING.

REACTOR SAFEGUARDS EXAMINATION

THE PURPOSE OF THIS EXAMINATION IS TO DETERMINE IF THE CREW OF A SHIP WITH A NEW CORE IS PREPARED TO OPERATE THE NUCLEAR PROPULSION PLANT, PARTICULARLY FROM A REACTOR SAFETY AND RADIATION CONTROL POINT OF VIEW. RESULTS OF THESE EXAMINATIONS ARE USED TO SUGGEST TO THE PROSPECTIVE COMMANDING OFFICERS AREAS WHERE FURTHER TRAINING IS NECESSARY.

THIS VERIFICATION OF OPERATOR KNOWLEDGE LEVEL IS DONE DIRECTLY BY MY STAFF FOR SHIPS WHICH ARE NEWLY CONSTRUCTED OR BEING REFUELED. A TEAM COMPOSED OF A MINIMUM OF FOUR MEMBERS, REPRESENTING FOUR KEY AREAS OF OPERATOR SPECIALTY, IS ASSEMBLED AND HEADED BY A SENIOR MEMBER OF MY STAFF. THEY GO TO THE NEW CONSTRUCTION OR OVERHAUL FACILITY AND SPEND SEVERAL DAYS INTERVIEWING MEMBERS OF THE NUCLEAR WATCH SECTIONS, OBSERVING PRACTICAL DRILLS AND EVOLUTIONS AND INSPECTING THE MATERIAL CONDITION OF THE SHIP.

AT THE CONCLUSION OF THE EXAMINATION THE TEAM LEADER REPORTS TO ME DIRECTLY WITH A PASS OR FAIL RECOMMENDATION. I PERSONALLY APPROVE ALL RESULTS OF THESE EXAMINATIONS. THIS INSPECTION, CALLED A REACTOR SAFEGUARDS EXAMINATION, OCCURS ABOUT FOUR TO SIX WEEKS PRIOR TO INITIAL CRITICALITY OF THE REACTOR. IMMEDIATELY PRIOR TO INITIAL CRITICALITY, THE SHIPYARD COMMANDER

OR THE SUPERVISOR OF SHIPBUILDING, AS APPROPRIATE, REQUESTS PERMISSION BY NAVAL MESSAGE TO CONDUCT OPERATIONS WITH THE REACTOR AT POWER. I PERSONALLY AUTHORIZE INITIAL CRITICALITY AND SUBSEQUENT TESTING WITH THE REACTOR AT POWER.

THE PROCEDURE I HAVE JUST DESCRIBED IS ALSO USED IN THE CASE OF A LAND-BASED PROTOTYPE WITH A NEW REACTOR CORE.

FOLLOWING THIS INITIAL SAFEGUARDS EXAMINATION, EACH CREW IS EXAMINED ANNUALLY. IN THE PAST THESE ANNUAL EXAMINATIONS HAVE BEEN CONDUCTED BY SENIOR MEMBERS OF MY STAFF. ON MARCH 13, 1967, THE CHIEF OF NAVAL OPERATIONS ESTABLISHED NAVAL NUCLEAR PROPULSION EXAMINING BOARDS ON THE STAFFS OF THE COMMANDER-IN-CHIEF ATLANTIC AND PACIFIC FLEETS.

OPERATIONAL REACTOR SAFEGUARDS EXAMINATION

THE FLEET NUCLEAR PROPULSION EXAMINING BOARDS PROVIDE AN OUTSIDE, INDEPENDENT EVALUATION OF SHIPBOARD TRAINING, ALONG WITH OTHER FACETS OF PROPULSION PLANT OPERATIONS, ADMINISTRATION, AND MAINTENANCE. THESE BOARDS ARE HEADED BY A SENIOR CAPTAIN WHO HAS SERVED AS COMMANDING OFFICER OF A NAVAL NUCLEAR-POWERED SHIP. THE ATLANTIC FLEET NUCLEAR PROPULSION EXAMINING BOARD IS COMPOSED OF SUFFICIENT OFFICERS TO CONDUCT OPERATIONAL REACTOR SAFEGUARDS EXAMINATIONS ON THREE SHIPS SIMULTANEOUSLY. THE PACIFIC FLEET BOARD IS

MANNED TO CONDUCT TWO OPERATING EXAMINATIONS SIMULTANEOUSLY. EACH TEAM CONDUCTING AN OPERATIONAL REACTOR SAFEGUARDS EXAMINATION IS COMPOSED OF FOUR NUCLEAR TRAINED OFFICERS. THE SENIOR TEAM MEMBER HAS PREVIOUSLY SERVED AS COMMANDING OFFICER OF A NAVAL NUCLEAR-POWERED SHIP; THE REMAINING THREE OFFICERS HAVE SERVED AS ENGINEER OFFICER IN NAVAL NUCLEAR-POWERED SHIPS. THE NUCLEAR PROPULSION EXAMINING BOARDS CONDUCT OVER 180 EXAMINATIONS A YEAR OF NUCLEAR-POWERED SHIPS OPERATING AT SEA AS WELL AS RADIOLOGICAL SUPPORT FACILITIES ON SUPPORT SHIPS AND SHORE BASES. THESE EXAMINATIONS LAST FROM TWO TO FIVE DAYS AND LOOK INTO EVERY ASPECT OF NUCLEAR PROPULSION PLANT OR RADIOLOGICAL SUPPORT FACILITY OPERATIONS, ADMINISTRATION, AND TRAINING. CASUALTY DRILLS AND EVOLUTIONS ARE CONDUCTED FOR THE BOARD TO EVALUATE. OPERATORS ARE INTERVIEWED BY BOARD MEMBERS TO DETERMINE THEIR LEVEL OF KNOWLEDGE. ADDITIONALLY, THE BOARD CONDUCTS A DETAILED INSPECTION OF ENGINEERING OR RADIOLOGICAL SUPPORT FACILITY SPACES TO DETERMINE ADEQUACY OF MATERIAL CONDITIONS AND CLEANLINESS. UPON COMPLETION OF THE EXAMINATION A GRADE IS ASSIGNED AND A TREND IS DETERMINED RELATIVE TO THE SHIP'S PREVIOUS PERFORMANCE.

THE OPERATIONAL REACTOR SAFEGUARDS EXAMINATION REPORT PROVIDES THE INDIVIDUAL SHIP WITH IMMEDIATE FEEDBACK THAT IT CAN USE TO IMPROVE TRAINING AND OPERATION. THESE REPORTS ALSO

PROVIDE NAVAL REACTORS THE OPPORTUNITY FOR AN OVERALL LOOK AT FLEET NUCLEAR PROPULSION PLANT TRAINING AS WELL AS HOW INDIVIDUAL SHIPS ARE DOING. THE RESULTS OF THE EXAMINATION, INCLUDING THE GRADE AND TREND ASSIGNED, ARE REPORTED TO THE SHIPS OPERATIONAL COMMANDER, THE CHIEF OF NAVAL OPERATIONS AND TO ME. SHIPS THAT HAVE SIGNIFICANT WEAK AREAS ARE REQUIRED TO SUBMIT A WRITTEN REPORT OF CORRECTIVE ACTION WITHIN A SPECIFIED PERIOD FOLLOWING THE EXAMINATIONS. EXAMINATION REPORTS ARE USED TO UPGRADE THE PERFORMANCE AND TRAINING OF THE CREWS OF ALL NUCLEAR-POWERED SHIPS AND RADIOLOGICAL SUPPORT FACILITIES; AND, WHEN NECESSARY, TO INITIATE CHANGES IN THE OVERALL TRAINING PROGRAM INCLUDING NUCLEAR POWER SCHOOL AND PROTOTYPE TRAINING.

I DISCUSS THE RESULTS OF THE EXAMINATION WITH EACH COMMANDING OFFICER BY PHONE - BECAUSE FOR MOST PART THEY ARE IN VARIOUS PARTS OF THE WORLD. IF I CONSIDER IT NECESSARY, I ASK HIM TO WRITE ME AND TELL ME WHAT HE WILL DO TO IMPROVE THE PERFORMANCE OF HIS SHIP.

PERSONNEL FROM MY STAFF CONDUCT ANNUAL EXAMINATIONS AT THE LAND-BASED PROTOTYPES. A WRITTEN REPORT OF CORRECTIVE ACTION IS REQUIRED IN ALL CASES WITHIN A SPECIFIED PERIOD FOLLOWING THE EXAMINATION. AGAIN, THESE SAFEGUARDS EXAMINATIONS REPORTS PROVIDE FEEDBACK USEFUL IN IMPROVING THE TRAINING PROGRAM.

INCIDENT REPORTS

TO ENSURE THAT I AM KEPT FULLY AWARE OF PROBLEMS ASSOCIATED WITH NAVAL NUCLEAR POWERED PLANTS (BOTH SHIP AND PROTOTYPE), I REQUIRE THE COMMANDING OFFICER OR PROTOTYPE MANAGERS TO REPORT TO ME DIRECTLY ANY EQUIPMENT MALFUNCTION, OPERATIONAL DIFFICULTY, OR DEVIATION FROM PRESCRIBED PROCEDURES. THESE WRITTEN "INCIDENT REPORTS" ARE IN ADDITION TO OTHER FORMAL NAVY REQUIREMENTS AND ARE UNIQUELY DESIGNED TO SATISFY THE TECHNICAL REQUIREMENTS OF NUCLEAR POWER. THEY DESCRIBE IN DETAIL WHAT HAS HAPPENED, WHY IT HAPPENED, AND WHAT HAS ALREADY BEEN DONE LOCALLY TO CORRECT THE PROBLEM AND RREVENT A RECURRENCE. I READ EVERY REPORT AND ENSURE THAT ADEQUATE CORRECTIVE ACTION IS TAKEN IN EACH CASE. MY STAFF REVIEWS EACH REPORT IN DEPTH IN THEIR PARTICULAR AREA OF INTEREST. THEY ALSO MONITOR FOR TRENDS INDICATIVE OF A PROBLEM COMMON TO SEVERAL PLANTS OR COMMON ONLY TO ONE TYPE OF PLANT.

THIS RAPID FEEDBACK OF DESIGN, MATERIAL, PERSONNEL, OR PROCEDURAL PROBLEMS HAS PROVEN INVALUABLE IN IMPROVING THE RELIABILITY, SAFETY AND PERFORMANCE, BOTH OF THE EQUIPMENT AND OF THE OPERATORS. MANY TIMES APPARENTLY INCONSEQUENTIAL FAILURES, WHEN INVESTIGATED FULLY, HAVE LEAD TO ACTIONS WHICH PREVENTED MORE SERIOUS INCIDENTS FROM OCCURRING.

THESE FLEET AND PROTOTYPE INCIDENT REPORTS ALSO SOMETIMES

DESCRIBE CASES WHERE, HAD THE INDIVIDUAL BEEN BETTER TRAINED, HE MIGHT HAVE AVOIDED AN ERROR IN THE PERFORMANCE OF HIS JOB. LESSONS LEARNED FROM THESE REPORTS ARE PERIODICALLY PROMULGATED TO THE FLEET IN NAVAL REACTORS TECHNICAL BULLETIN ARTICLES, AND CHANGES MADE, IF NEEDED, TO DESIGN AND TO THE OVERALL TRAINING PROGRAM.

MONITOR WATCH PROGRAM

I PREVIOUSLY INDICATED THE IMPORTANCE OF INSPECTIONS IN REGARD TO MAINTAINING HIGH STANDARDS. THESE INSPECTIONS COME IN MANY WAYS AND FORMS BUT ONE OF THE MOST EFFECTIVE IS THE MONITOR WATCH. THE MONITOR WATCH IS A SURVEILLANCE CONDUCTED BY SOMEONE, KNOWLEDGEABLE IN A GIVEN AREA, TO OBSERVE AND DETECT DEFICIENCIES IN PERFORMANCE THAT OCCUR DURING THE PERIOD OF OBSERVATION. EXPERIENCE HAS SHOWN THAT THESE MONITOR WATCHES SHOULD BE AT LEAST TWO HOURS IN LENGTH SO THAT THE INSPECTOR BECOMES PART OF THE BACKGROUND AND THE CREW PERFORMS AS THEY WOULD WITHOUT A MONITOR PRESENT. I REQUIRE MY REPRESENTATIVES IN THE FIELD (SHIPYARDS AND PROTOTYPES) TO CONDUCT MONITOR WATCHES PERIODICALLY PARTICULARLY DURING THE NIGHT, AND REPORT THE RESULTS DIRECTLY TO ME. THE FORCE COMMANDERS HAVE A SIMILAR MONITOR WATCH SYSTEM IN WHICH NUCLEAR TRAINED STAFF MEMBERS CONDUCT MONITOR WATCHES ON THE SHIPS ASSIGNED TO THEIR COMMAND. I RECEIVE COPIES OF THE MONITOR WATCH REPORTS THAT ARE SUBMITTED UNDER THE FORCE

COMMANDERS SYSTEM. IN ADDITION, MEMBERS OF THE NUCLEAR PROPULSION EXAMINING BOARD CONDUCT MONITOR WATCHES ON SHIPS IN THE AREA WHERE THEY HAVE JUST COMPLETED AN EXAMINATION. THE MONITOR WATCH MAY IDENTIFY PROBLEMS IN ANY PROPULSION PLANT AREA INCLUDING TRAINING. MONITOR WATCH REPORTS, THEN, ARE ANOTHER FEEDBACK SYSTEM TO THE OVERALL TRAINING PROGRAM.

COMMANDING OFFICER'S LETTERS

I REQUIRE EVERY COMMANDING OFFICER OF A NUCLEAR POWERED SHIP TO WRITE A PERIODIC PERSONAL LETTER TO ME DISCUSSING PROPULSION PLANT PROBLEMS. INCLUDED IN THIS LETTER IS A LISTING OF ALL RECURRING NUCLEAR PROPULSION PLANT TRAINING THE COMMANDING OFFICER HAS CONDUCTED ON HIS SHIP SINCE HIS LAST LETTER. THIS LISTING CONTAINS THE TRAINING SUBJECT, DATE, WHO ATTENDED BY CATEGORY, (FOR EXAMPLE ALL EOOW'S), NUMBER OF PEOPLE ATTENDING EACH SESSION, WHO MONITORED THE TRAINING, GRADES ON EXAMINATIONS GIVEN, DRILLS AND EVOLUTIONS CONDUCTED FOR TRAINING, AND SCHOOLS ATTENDED BY NUCLEAR TRAINED PERSONNEL. THIS TRAINING SUMMARY IS EVALUATED BY MYSELF AND MEMBERS OF MY STAFF FOR ADEQUACY OF CONTENT AND EXTENT. IF IT IS NOT CONSIDERED ADEQUATE, THE COMMANDING OFFICER OR IN SOME CASES HIS BOSS IS CALLED AND THE WEAKNESSES POINTED OUT. MY DIRECT AND PERSONAL INTEREST IN EACH SHIP'S TRAINING SHOULD BE OBVIOUS.

NUCLEAR PROPULSION PLANT TRAINING - FINAL COMMENTS

I HAVE PROVIDED A DETAILED DESCRIPTION OF THE NAVY NUCLEAR PROPULSION PLANT TRAINING PROGRAM. HIGH STANDARDS OF PERFORMANCE ARE MAINTAINED THROUGH USE OF PROVEN TRAINING METHODS WITH RELIABLE QUALITY CONTROL CHECKS TO ENSURE THAT TRAINING IS CONDUCTED PROPERLY. BOTH THEORETICAL AND PRACTICAL TRAINING ARE INCLUDED. THE RESULTS OF SEVERAL DIFFERENT INSPECTION AND REPORTING SYSTEMS ENABLE ME CONTINUOUSLY TO EVALUATE THE TRAINING BEING CONDUCTED FOR ITS ADEQUACY. THESE RESULTS ARE ALSO EVALUATED TO DETERMINE AREAS WHERE NUCLEAR POWER SCHOOL AND PROTOTYPE TRAINING NEEDS IMPROVEMENT OR MODIFICATION. IN THIS MANNER, THE OPERATIONAL EXPERIENCE OF THE NUCLEAR PROPULSION PLANT OPERATORS IS CONTINUOUSLY FACTORED BACK INTO THE TRAINING PROGRAM.

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MARCH 2003

ENVIRONMENTAL MONITORING AND DISPOSAL OF RADIOACTIVE WASTES FROM U.S. NAVAL NUCLEAR-POWERED SHIPS AND THEIR SUPPORT FACILITIES

NAVAL NUCLEAR PROPULSION PROGRAM
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ENVIRONMENTAL MONITORING AND DISPOSAL OF RADIOACTIVE WASTES FROM U.S. NAVAL NUCLEAR-POWERED SHIPS AND THEIR SUPPORT FACILITIES 2002

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ABSTRACT

This report assesses the environmental effect of disposal of radioactive wastes originating from U.S. naval nuclear propulsion plants and their support facilities. The total long-lived gamma radioactivity in liquids discharged to all ports and harbors from all naval nuclear-powered ships and supporting tenders, naval bases, and shipyards was less than 0.002 curie in 2002. To put this small quantity of radioactivity into perspective, it is less than the quantity of naturally occurring radioactivity in the volume of saline harbor water occupied by a single submarine. This report confirms that procedures used by the Navy to control releases of radioactivity from U.S. naval nuclear-powered ships and their support facilities are effective in protecting the environment and the health and safety of the general public. These procedures have ensured that no member of the general public has received measurable radiation exposure as a result of operations of the Naval Nuclear Propulsion Program.

The successful radiological deactivation and closures of Ingalls Shipbuilding radiological facilities in 1982 and of the Charleston and Mare Island Naval Shipyards in 1996 demonstrate that the stringent control over radioactivity exercised by the Naval Nuclear Propulsion Program from its inception has been successful in preventing radiological contamination of the environment and in avoiding expensive radiological liabilities at shipyards.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

SUMMARY

The radioactivity in materials discussed in this report originates in the pressurized water reactors of U.S. naval nuclear-powered ships. As of the end of 2002, the U.S. Navy had 73 nuclear-powered submarines, 9 nuclear-powered aircraft carriers, and 2 moored training ships in operation. Facilities involved in construction, maintenance, overhaul, and refueling of these nuclear propulsion plants include six shipyards, two tenders, and five naval bases. This report describes disposal of radioactive liquid, transportation and disposal of solid wastes, and monitoring of the environment to determine the effect of radioactive releases, and updates reports on this subject issued by the Navy in references 1 through 6 (references are listed on page 30). This report concludes that radioactivity associated with U.S. naval nuclear-powered ships has had no discernible effect on the quality of the environment. A summary of the radiological information supporting this conclusion follows:

From the start of the Naval Nuclear Propulsion Program, the policy of the U.S. Navy has been to reduce to the minimum practicable the amounts of radioactivity released into harbors. Since 1971, the total long-lived gamma radioactivity released each year within 12 miles from shore from all U.S. naval nuclear-powered ships and their support facilities has been less than 0.002 curie; this includes all harbors, both U.S. and foreign, entered by these ships.

As a measure of the significance of these data, the total quantity of long-lived radioactivity released within 12 miles of shore in any of the last 32 years is less than the quantity of naturally occurring radioactivity in the volume of saline harbor water occupied by a single nuclear-powered submarine. In addition, if one person were able to drink the entire amount of radioactivity discharged into any harbor in any of the last 32 years, that person would not exceed the annual radiation exposure permitted for an individual worker by the Nuclear Regulatory Commission

Environmental monitoring is conducted by the U.S. Navy in U.S. and foreign harbors frequented by U.S. naval nuclear-powered ships. This monitoring consists of analyzing harbor sediment, water, and marine life samples for radioactivity associated with naval nuclear propulsion plants; radiation monitoring around the perimeter of support facilities; and effluent monitoring. Environmental samples from each of these harbors are also checked at least annually by a Department of Energy laboratory to ensure analytical procedures are correct and standardized.

Independent environmental monitoring has been conducted by the Environmental Protection Agency in U.S. harbors during the past several decades. The results of these extensive, detailed surveys have been consistent with Navy results. These surveys have again confirmed that U.S. naval nuclear-powered ships and support facilities have had no discernible effect on the radioactivity of the environment.

RADIOACTIVE LIQUID PROCESSING AND CONTROL

Policy and Procedures Minimizing Release of Radioactivity in Harbors

The policy of the U.S. Navy is to reduce to the minimum practicable the amounts of radioactivity released to the environment, particularly within 12 miles of shore. This policy is consistent with applicable recommendations issued by the Federal Radiation Council (incorporated into the Environmental Protection Agency in 1970), U.S. Nuclear Regulatory Commission, National Council on Radiation Protection and Measurements, International Commission on Radiological Protection, International Atomic Energy Agency, and National Academy of Sciences—National Research Council (references 7 through 16). Keeping releases small minimizes the radioactivity available to build up in the environment or to concentrate in marine life. To implement this policy of minimizing releases, the Navy has issued standard instructions defining radioactive release limits and procedures to be used by U.S. naval nuclear-powered ships and their support facilities.

Source of Radioactivity

In the shipboard reactors, pressurized water circulating through the reactor core picks up the heat of nuclear reaction. The reactor cooling water circulates through a closed piping system to heat exchangers, which transfer the heat to water in a secondary steam system isolated from the primary cooling water. The steam is then used as the source of power for the propulsion plant, as well as for auxiliary machinery. When reactor coolant water expands as a result of being heated to operating temperature, the coolant passes through an ion exchange resin bed for purification before being transferred to holding tanks.

The principal source of radioactivity in liquid effluents is trace amounts of corrosion and wear products from reactor plant metal surfaces in contact with reactor cooling water. Radionuclides with half-lives of approximately one day or greater in these corrosion and wear products include tungsten-187, chromium-51, hafnium-181, iron-59, iron-55, nickel-63, niobium-95, zirconium-95, tantalum-182, manganese-54, cobalt-58, and cobalt-60. The most predominant of these is cobalt-60, which has a half-life of 5.3 years. Cobalt-60 also has the most restrictive concentration limit in water (as listed by organizations that set radiological standards in references 7 and 8 for these corrosion and wear radionuclides). Therefore, cobalt-60 is the primary radionuclide of interest for naval nuclear propulsion plants.

Radioactivity Removal From Liquid at Shore Facilities

Radioactive liquids at shore facilities are collected in stainless steel tanks and pumped through a processing system to remove most of the radioactivity (exclusive of tritium) prior to collection in a clean tank for potential reuse. Even after processing to approximately 10^{-8} microcuries of gamma radioactivity per milliliter, reactor coolant is not discharged to surrounding waters. Figure 1 shows a simplified block diagram of the

liquid processing system, which consists of particulate filters, activated carbon bed filters, mixed hydrogen hydroxyl resin, and colloid removal resin beds. This type of processing system has been developed and used successfully to produce high-quality water containing very low radioactivity levels. This high-quality processed water is either returned to nuclear-powered ships or evaporated.

Liquid Releases in Harbors

The total amount of long-lived gamma radioactivity released into harbors and seas within 12 miles of shore has been less than 0.002 curie during each of the last 32 years. This total is for releases from U.S. naval nuclear-powered ships and from the supporting shipyards, tenders, and submarine bases, and at operating bases and home ports in the U.S. and overseas and all other U.S. and foreign ports that were visited by naval nuclear-powered ships.

To put this small quantity of radioactivity into perspective, it is less than the quantity of naturally occurring radioactivity (reference 17) in the volume of saline harbor water occupied by a single nuclear-powered submarine.

Short-Lived Radionuclides

Reactor coolant also contains short-lived radionuclides with half-lives of seconds to hours. Their highest concentrations in reactor coolant are from nitrogen-16 (7 second half-life), nitrogen-13 (10 minute half-life), fluorine-18 (1.8 hour half-life), argon-41 (1.8 hour half-life) and manganese-56 (2.6 hour half-life). For the longest-lived of these, about a day after discharge from an operating reactor, the concentration is reduced to one-thousandth of the initial concentration; and in about 2 days the concentration is reduced to one-millionth. Further, essentially all of the water is held onboard ship or transferred to shore facilities for processing and potential reuse and not discharged. Consequently, these short-lived radionuclides are not important for liquid release considerations.

Fission Product Radionuclides

Fission products produced from fuel in the reactor, including iodine and the fission gases krypton and xenon, are retained within the fuel elements. However, trace quantities of naturally occurring uranium impurities in reactor structural materials release small amounts of fission products to reactor coolant. The concentrations of fission products and the volumes of reactor coolant released are so low, however, that the total radioactivity attributed to long-lived fission product radionuclides comprises only a small fraction of the total long-lived gamma radioactivity releases discussed elsewhere in this report.

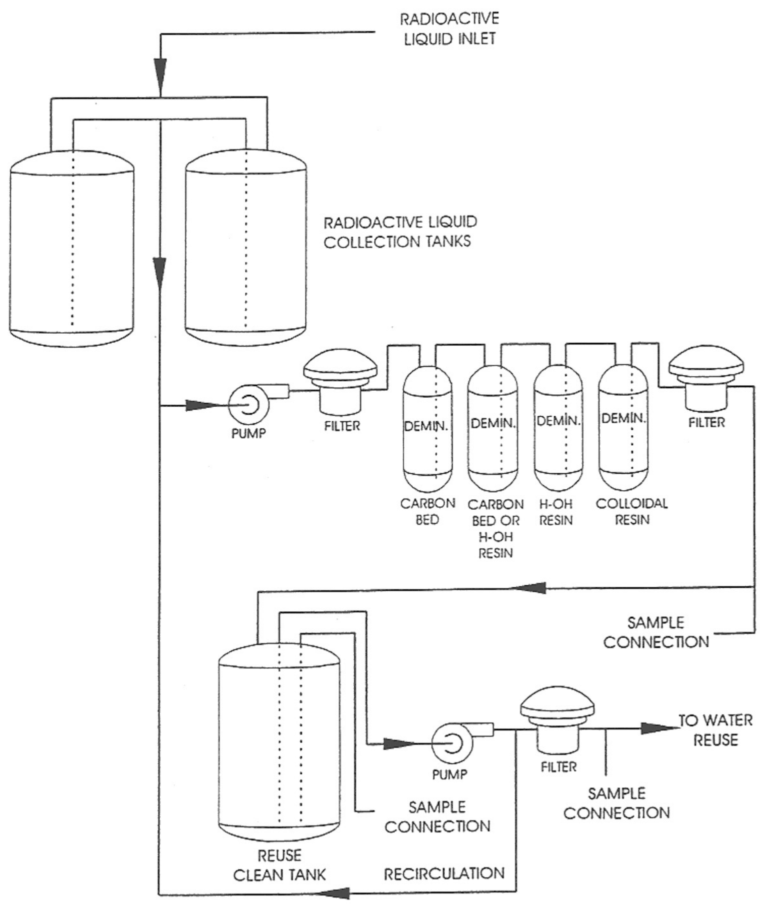


Figure 1
Simplified Diagram of Radioactive Liquid Processing System

Tritium

Tritium is a radioactive isotope of hydrogen. Trace amounts of tritium are formed in reactor coolant systems when neutrons interact with deuterium (a non-radioactive isotope of hydrogen) which is naturally present in about 0.015 percent of seawater. Although tritium does have a half-life of 12 years, the radiation it produces is of such low energy as to be environmentally insignificant. In fact, the safety guidelines issued by the International Commission on Radiological Protection, the National Council on Radiation Protection and Measurements, the U.S. Nuclear Regulatory Commission, and other standard-setting agencies permit the presence of 100 times as much tritium as cobalt 60. The tritium produced by naval nuclear reactors is in the oxide form, chemically indistinguishable from water. Therefore, unlike other radionuclides, it neither concentrates significantly in marine life nor collects on sediment.

Tritium occurs naturally in the environment, generated by cosmic radiation in the upper atmosphere. According to reference 18, cosmic radiation produces about 4 million curies of tritium per year. This means that there is a global inventory of about 70 million curies of tritium at any given time, about 45 million curies of which are in the oceans (reference 19). In comparison, the amount of tritium released each year from all U.S. naval nuclear-powered ships and their supporting tenders, bases, and shipyards has always been less than 200 curies—and virtually all of that was released into the ocean more than 12 miles from shore. This amount is less than the tritium released annually to the environment by a single commercial nuclear power station (reference 20). Further, the amount of tritium in water released within 12 miles of shore by U.S. naval nuclear-powered ships and their support facilities is less than one curie.

Because the amount of tritium occurring naturally in the environment is so large, the amount produced by U.S. naval reactors is too small to have any measurable effect on the environment. Therefore, tritium has not been combined with data on other radionuclides in this report.

Carbon-14

Carbon-14 is also formed in small quantities in reactor coolant systems as a result of neutron interactions with nitrogen and oxygen. Carbon-14 decays with a half-life of 5,730 years. Only low energy beta radiation is emitted during decay. As a result, the radioactivity concentration guides for carbon-14 in its chemical form in air issued by the International Commission on Radiological Protection, the National Council on Radiation Protection and Measurements, the U.S. Nuclear Regulatory Commission, and other standard-setting organizations are 60 times higher than for cobalt-60.

Carbon-14 occurs naturally in the environment. It is generated from cosmic radiation interactions with nitrogen and oxygen in the upper atmosphere and oxidized to form carbon dioxide. Carbon-14 is chemically indistinguishable from other isotopes of carbon. The carbon dioxide diffuses and convects throughout the atmosphere and enters the earth's carbon cycle. Reference 21 states that the earth's natural carbon-14

inventory is estimated to be about 250 million curies, of which approximately 95 percent resides in the oceans. The total amount of carbon-14 released annually from the operation of all U.S. naval nuclear-powered ships and their supporting tenders, bases, and shipyards has been less than 100 curies, which is far less than the natural carbon-14 production rate of 40,000 curies per year (reference 21). Since the inventory of naturally occurring carbon-14 is so large, it is extremely unlikely that releases from naval nuclear reactors could result in a measurable change in the background concentration of carbon-14.

Liquid Releases at Sea

Radioactive liquids incidental to the operation of the nuclear propulsion plants are released at sea under strict controls. These ocean releases are consistent with recommendations the Council on Environmental Quality made in 1970 to the President in reference 22, and consistent with the Marine Protection, Research, and Sanctuaries Act, reference 23. Procedures and limits for ocean releases have been consistent with recommendations made by the National Academy of Sciences—National Research Council in reference 11 and by the International Atomic Energy Agency in reference 12. Navy releases have contained much less radioactivity than the recommendations of these reports. Since 1973, the total long-lived gamma radioactivity released more than 12 miles from shore by U.S. naval nuclear-powered ships and supporting tenders has been less than or equal to 0.4 curie per year. Releases occur at different times of the year in the open sea at long distances from land in small amounts, and under rapid dispersal conditions due to wave action. This 0.4 curie is less than the naturally occurring radioactivity (reference 17) in a cube of sea water approximately 100 yards on a side.

Loss of USS THRESHER and USS SCORPION

Two U.S. naval nuclear-powered submarines have been lost at sea in the Atlantic Ocean. The submarine THRESHER sank on 10 April 1963, 200 miles southeast of Maine in water 8,500 feet deep. The submarine SCORPION sank on 22 May 1968, 400 miles southwest of the Azores in more than 10,000 feet of water. The reactors used in all U.S. naval submarines and surface ships are designed to minimize potential hazards to the environment even under the most severe casualty conditions, such as the actual sinking of the ship. First, the reactor core is designed so that it is physically impossible for it to explode like a bomb. Second, the reactor fuel elements are made of materials that are extremely corrosion resistant, even in seawater. The reactor core could remain submerged in seawater for centuries without releases of fission products while the radioactivity decays, since the protective cladding on the fuel elements corrodes only a few millionths of an inch per year. Thus, in the event of a serious accident where the reactor is completely submerged in seawater, the fuel elements will remain intact for an indefinite period of time, and the radioactive material contained in these fuel elements should not be released. The maximum rate of release and dispersal of the radioactivity in the ocean, even if the protective cladding on the fuel were destroyed, would be so low as to be insignificant.

Radioactive material could be released from this type of reactor only if the fuel elements were actually to melt and, in addition, the high-strength, all-welded reactor system boundary were to rupture. The reactor's many protective devices and inherent self-regulating features are designed to prevent any melting of the fuel elements. Flooding of a reactor with seawater furnishes additional cooling for the fuel elements and so provides added protection against the release of radioactive fission products.

Radiation measurements, water samples, bottom sediment samples, and debris collected from the area where THRESHER sank were analyzed for radioactivity shortly after the sinking and again in 1965 by various laboratories. Similarly, seawater and bottom sediment samples taken near SCORPION's hull were analyzed for radioactivity. In 1977, 1983, 1986, and 1998, follow-up samples of water, sediment, and marine life were collected from near the THRESHER debris. In 1979, 1986, and 1998, follow-up samples of water, sediment, and marine life were collected from near the SCORPION debris. None of these samples showed any evidence of release of radioactivity from the reactor fuel elements in either THRESHER or SCORPION.

Cobalt-60 released from both THRESHER and SCORPION coolant systems was detectable at low levels in the sediment samples in the debris areas. Cobalt-60 was not detectable in samples of water or marine life. The maximum cobalt-60 concentration measured in the sediment at either site during the 1998 survey was 2.02 picocuries per gram; most samples were much less than this concentration. This is less than one-tenth of the concentration of naturally occurring radioactivity in the sediment. For perspective, if a person's diet contained cobalt-60 at the maximum concentration detected in the sediment, that person would receive less than 10 percent of the radiation exposure received from natural background radioactivity.

SCORPION carried two torpedoes with nuclear weapons containing plutonium. While the monitoring campaign was for the express purpose of assessing the impacts from the nuclear reactor, sediment, water, and marine life samples collected at the SCORPION site in 1986 and 1998 were also analyzed for plutonium. Total plutonium radioactivity concentrations and the relative concentrations of plutonium isotopes were typical of background concentrations due to fallout from nuclear weapons testing. Thus, there is no evidence of leakage of plutonium from nuclear weapons that were on the submarine when it sank.

Summary information on the radiological surveys of the THRESHER and SCORPION sites was published in reference 24. In 1993, the Navy issued detailed unclassified reports of the radiological environmental monitoring of the THRESHER and SCORPION sites, references 25 and 26. The Navy also released a report in 2000 of the environmental monitoring conducted in 1998, reference 27. The conclusions of this report confirm the results of previous environmental monitoring expeditions and demonstrate that the THRESHER and SCORPION have had no discernible effect on the radioactivity in the environment.

SOLID RADIOACTIVE WASTE DISPOSAL

During maintenance and overhaul operations, solid low-level radioactive wastes (consisting of contaminated rags, plastic bags, paper, filters, ion exchange resin and scrap materials) are collected from nuclear-powered ships and their support facilities. These low-level radioactive materials are required to be strictly controlled to prevent loss. These controls include naval accountability procedures, which require serialized tagging and marking and signatures by radiologically trained personnel.

Table 1 summarizes the total radioactivity and volumes of radioactive solid waste disposed of during the last 5 years. Table 1 includes all waste generated by U.S. naval nuclear-powered ships and the listed support facilities because all radioactive solid waste generated by U.S. nuclear-powered ships is transferred to the listed facilities. The quantity of solid radioactive waste in any one year from a particular facility depends on the amount and type of support work performed that year. Table 1 does not include spent fuel or other classified radioactive components shipped to Department of Energy facilities.

Figure 2 shows that the total annual volume of solid low-level radioactive waste was substantially reduced in the 1970s, despite increasing numbers of nuclear-powered ships. This reduction was accomplished simultaneously with reduction in personnel radiation exposure, as described in reference 28. This reduction was accomplished by several techniques, including a total containment concept for radiological work, which minimizes the spread of radioactivity to non-radioactive materials; use of preplanning and mockups to minimize rework; reusing rather than disposing of tools and equipment; use of radioactive liquid processing procedures that minimize depletion of processing media; use of compaction equipment and efficient packaging to fully use space in disposal containers; use of licensed commercial radioactive waste incineration, compaction, and radioactive metal recycling services; and separating solid waste that requires special disposal owing to its radioactive content from that which does not. The latter is achieved by work site controls and by use of sensitive equipment to detect radioactivity only slightly greater in concentration than that found in natural materials such as soil, rocks, water, and biological matter (see reference 19), thus requiring the material to be handled as radioactive for waste disposal purposes. Material that passes the screening provided by this sensitive detection equipment can be disposed of as ordinary waste. Challenging goals are set by each shipyard to ensure continuing management attention to minimizing the generation of waste in radiological work.

The annual volume of solid low-level radioactive waste disposed of in 2002 by the entire Naval Nuclear Propulsion Program, as shown in Table 1, could be contained in a cube measuring about 10 yards on a side. The total annual volume is less than 1 percent of the total volume of solid low-level radioactive waste buried in commercial disposal sites in the States of Washington, South Carolina, and Utah each year (reference 29).

Solid radioactive waste materials are packaged in strong, tight containers, shielded as necessary, and shipped to burial sites licensed by the U.S. Nuclear Regulatory Commission or a State under agreement with the Nuclear Regulatory Commission. Solid radioactive materials from naval nuclear-powered ships have not been dumped at sea since 1970, when the Navy issued procedures prohibiting sea disposal of solid radioactive materials. Shipyards and other shore facilities have never been permitted to dispose of radioactive solid wastes by burial on their own sites.

The Low-Level Radioactive Waste Policy Amendments Act of 1985 establishes that the States are responsible, either individually or in multi-State compacts, for providing for the disposal of low- level radioactive waste from private and non-Department of Energy Federal Government generators. Under this law, a waste compact may prohibit disposal of waste from outside the compact. The Northwest Compact site in Richland, Washington, accepts waste only from the Northwest and Rocky Mountain Compacts, which include Navy facilities in Washington and Hawaii.

The Atlantic Compact site in Barnwell, South Carolina, currently accepts waste from every State. Over the next 5 years, however, the Barnwell site will limit waste acceptance from out-of-compact generators.

One other disposal site accepts low-level radioactive waste. A disposal site in Clive, Utah, is licensed by the State of Utah and is accessible to generators around the country, but is only licensed to accept waste with low concentrations of radioactivity.

In view of the increased disposal fees and the uncertain future of low-level radioactive waste disposal sites, a concerted effort was made in the early 1990's to reevaluate radioactive equipment in storage for potential future use and to dispose of that equipment for which no specific future need was identified. For example, some of this equipment was no longer needed due to the declining Fleet size. In addition, the closure of Mare Island and Charleston Naval Shipyards resulted in the disposal of much of the equipment from these facilities. The volume of low-level radioactive waste shipped from these two shipyards accounted for 66 percent of the total volume shipped during 1995. As a result of all of these factors, the amount of solid low-level radioactive waste shipped for disposal increased from 1990 through 1995, but has declined in recent years.

Table 1: Disposed Radioactive Solid Waste from U.S. Naval Nuclear-Powered Ships and Their Support Facilities for 1998 through 2002

FACILITY	1998		1999		2000		2001		2002	
	THOUSAND CUBIC FEET	CURIES	THOUSAND CUBIC FEET	CURIES	THOUSAND CUBIC FEET	CURIES	THOUSAND CUBIC FEET	CURIES	THOUSAND CUBIC FEET	CURIES
Kittery, Maine Portsmouth Naval Shipyard	1	18	2.0	17	1.2	1	1.3	19	1.3	13
Groton, New London, Connecticut Electric Boat Division, Naval Submarine Base	1	1	0.6	<1	1.5	<1	1.7	<1	1.0	<1
Newport News, Virginia Newport News Shipbuilding	1	2	2.3	18	1.7	1	2.3	11	3.3	25
Norfolk, Virginia Naval Shipyard and Tenders	3	56	5.1	46	1.9	69	2.7	153	1.9	281
San Diego, California Navy Bases	—	—	1.0	12	0.1	<1	1.3	159	0.6	35
Bremerton, Washington Puget Sound Naval Shipyard	14	49	15.7	45	20.1	42	6.5	19	8.9	21
Pearl Harbor, Hawaii Naval Shipyard and Intermediate Maintenance Facility	2	48	2.1	88	1.8	101	2.1	49	0.3	39
TOTAL	**22**	**174**	**28.8**	**227**	**28.3**	**216**	**18.0**	**411**	**17.3**	**415**

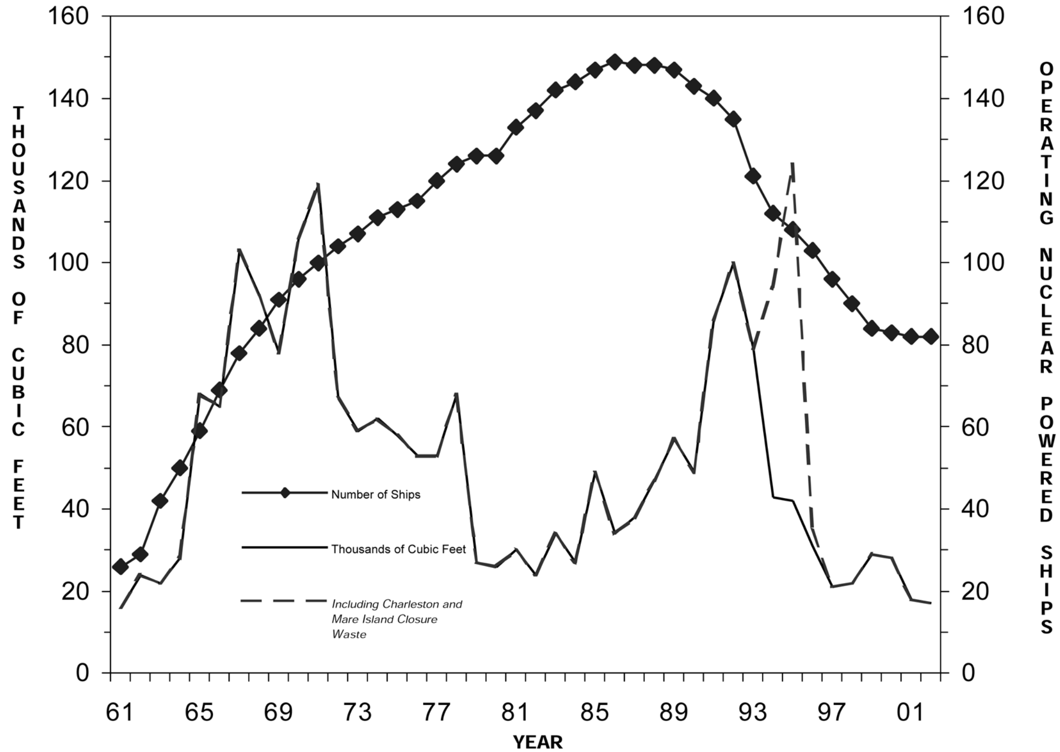
NOTES:

(1) This table includes all radioactive waste from tenders and nuclear-powered ships. This radioactivity is primarily cobalt-60. This radioactive waste is shipped to burial facilities licensed by the U.S. Nuclear Regulatory Commission or a State.

(2) Before 1999, volumes less than 500 cubic feet are reported as 1 thousand cubic feet. Beginning in 1999, volumes less than 100 cubic feet are reported as 0.1 thousand cubic feet. Activities less than 0.5 curie are reported as <1 curie.

(3) San Diego waste was included with Puget Sound Naval Shipyard waste in 1998.

Figure 2:
Radioactive Solid Waste Disposal in the Naval Nuclear Propulsion Program 1961 – 2002



Deactivation of Ingalls Shipbuilding Radiological Facilities

From 1958 to 1980, Ingalls Shipbuilding was engaged in the construction and overhaul of naval nuclear-powered ships in Pascagoula, Mississippi. The shipyard radiological facilities that supported this work were deactivated between 1980 and 1982 by removing and disposing all radioactive material associated with naval nuclear propulsion plants. Useful items, such as tools and equipment that were radioactively contaminated, were transferred to other organizations in the Naval Nuclear Propulsion Program. The remaining radioactive material was disposed of as solid waste.

Extensive radiological decommissioning surveys were performed to verify the removal of this radioactive material. Direct radiological surveys were performed on over 274,000 square feet of building and facility surfaces. Over 11,000 samples of these surfaces (as well as soil, ground cover, and concrete) were taken from all areas where radioactive work was previously performed. These samples were analyzed using sensitive laboratory equipment. In addition, both the State of Mississippi and the U.S. Environmental Protection Agency performed overcheck surveys of the deactivated facilities. After these surveys were completed, the Ingalls facilities were released for unrestricted use. Personnel who subsequently occupy these facilities will not receive measurable radiation exposure above natural background levels that exist in areas not affected by naval nuclear propulsion plant work. Reference 30 is the report of the survey of the Ingalls facilities by the Environmental Protection Agency (EPA).

Closure of Charleston and Mare Island Naval Shipyards

Mare Island Naval Shipyard was engaged in the construction, overhaul, and refueling of naval nuclear-powered ships from 1956 to 1995. Charleston Naval Shipyard was engaged in overhaul and refueling of naval nuclear-powered ships from 1962 to 1994. The 1993 round of the Base Closure and Realignment Act process directed closure of these shipyards. The radiological facilities at both Charleston and Mare Island have been deactivated in a manner similar to the process followed for deactivation of radiological facilities at Ingalls Shipbuilding. The shipyards were closed in April 1996.

As at Ingalls, extensive radiological decommissioning surveys were performed to verify the removal of radioactive material. At each shipyard, direct radiological surveys were performed on over 5 million square feet of building and facility surfaces, and over 40,000 samples of soil, ground cover, and concrete were analyzed using sensitive laboratory equipment. No cobalt-60 was detected, other than trace concentrations in a few localized areas. Simple, proven cleanup methods were used to remediate these areas. Both the radiological deactivation work and the survey work were performed by shipyard workers. The total amount of Program radioactivity remediated at each shipyard was about the same as that in a typical household smoke detector (2 to 3 microcuries).

The Navy's radiological verification surveys were completed in March 1996. Both the EPA and the States reviewed the Navy's survey data, conducted overcheck surveys, and agreed with the Navy's results. Personnel who occupy these facilities will not receive measurable radiation exposure above natural background levels.

The successful radiological deactivation and closures of Ingalls radiological facilities in 1982 and of Charleston and Mare Island in 1996 demonstrate that the stringent control over radioactivity exercised by the Naval Nuclear Propulsion Program from its inception has been successful in preventing radiological contamination of the environment and in avoiding expensive radiological liabilities at shipyards.

Mixed Radioactive and Hazardous Waste

Waste that is both radioactive and chemically hazardous is regulated under both the Atomic Energy Act and the Resource Conservation and Recovery Act (RCRA) as "mixed waste." Within the Naval Nuclear Propulsion Program, concerted efforts are taken to avoid commingling radioactive and chemically hazardous substances so as to minimize the potential for generation of mixed waste. For example, these efforts include avoiding the use of acetone solvents, lead-based paints, lead shielding in disposal containers, and chemical paint removers. As a result of Program efforts to avoid the use of chemically hazardous substances in radiological work, Program activities typically generate each year less than 20 cubic meters of mixed waste that requires off-site treatment following completion of on-site processing. As of the end of 2002, about 53 cubic meters of Program mixed waste is stored pending the availability of Department of Energy (DOE) and commercial mixed waste treatment capacity required to deal with over 600,000 cubic meters of non-Program DOE mixed waste. Mixed Waste Site Treatment Plans, approved by applicable Federal and State regulators pursuant to the requirements of the 1992 Federal Facility Compliance Act, identify specific treatment plans for each type of Program mixed waste.

Disposal of Decommissioned, Defueled Naval Reactor Plants

During the 1980s, the nuclear-powered submarines constructed in the 1950s and 1960s began to reach the end of their service life. In 1982, the Navy, with the DOE as a cooperating agency, published a Draft Environmental Impact Statement (EIS) on the disposal of decommissioned, defueled naval submarine reactor plants. The Draft EIS was widely distributed to individuals, environmental organizations, State and local officials, and other Federal agencies. All substantive comments were analyzed and addressed in the Final EIS, which was issued in 1984 (reference 24). Although the Navy had evaluated the option of disposing of the defueled ships by sinking at sea, the preferred option identified in the Final EIS was to dispose of the defueled reactor plants at a Federal disposal facility already used for low-level radioactive waste disposal. In December 1984, the Secretary of the Navy issued a Record of Decision to proceed with land disposal. In 1996, the Navy issued a Final EIS (reference 31) which evaluated the disposal of defueled reactor plants from cruisers and newer submarine classes. The

Navy and the DOE issued a Record of Decision to dispose of these defueled reactor plants by land disposal in the same manner.

A nuclear-powered ship is constructed with the nuclear power plant inside a single section of the ship, called the reactor compartment. Before the reactor compartment is disposed of, the nuclear fuel is removed and handled in the same manner as nuclear fuel removed during refueling of nuclear-powered ships. The defueled reactor compartments are removed from decommissioned nuclear-powered ships in drydocks at the Puget Sound Naval Shipyard in Bremerton, Washington. After removal from a ship, the reactor compartment is sealed and loaded onto a barge for transport to the Port of Benton on the Columbia River near the Department of Energy Hanford Site. At the Port of Benton, the reactor compartment is transferred to a land transporter, which carries the reactor compartment to the disposal trench on the Hanford Site. Further information on this process is contained in the Final EIS (reference 31). The first defueled reactor compartment was shipped to Hanford in 1986. In 2002, the Naval Nuclear Propulsion Program shipped 8 defueled reactor compartments , bringing the total number shipped to 110.

TRANSPORTATION OF RADIOACTIVE MATERIAL

Shipments of radioactive materials in the Naval Nuclear Propulsion Program must be made in accordance with applicable regulations of the U.S. Department of Transportation, the Department of Energy, and the Nuclear Regulatory Commission (NRC). The purpose of these regulations is to ensure that shipments of radioactive material are adequately controlled to protect the environment and the health and safety of the general public. These regulations apply to all radioactive material shipments and provide requirements for container design, certification, and identification pertaining to the specific quantity, type, and form of radioactivity being shipped.

In addition to the above, requirements for naval shipping container designs incorporate shielding and integrity specifications. These requirements provide for container design analysis, training and qualification of workers who construct containers, and quality control inspections during fabrication to ensure the containers will meet design requirements.

In addition to imposing requirements of Federal transportation regulations, the Navy has issued standard instructions to further control shipments of radioactivity associated with U.S. naval nuclear propulsion plants. These standard instructions result in a quality assurance program that includes inspections and assessments by independent organizations and senior management. Organizations making shipments are required to prepare local procedures, which direct the use of compliance checklists and management review to ensure compliance with applicable Department of Transportation, Navy, and disposal site requirements. Only specially trained, designated people, knowledgeable in shipping regulations, are permitted to authorize shipments of radioactive material.

Protective transportation services, such as signature security service or sealed shipping vehicles, are required for radioactive material shipments to ensure point-to-point control and traceability of each shipment from shipper to receiver. A readily accessible log of all shipments in transit is maintained to enable prompt identification and provide the basis for advice on the nature of the shipment. Receivers must make return receipts in writing to ensure that radioactive material has not been lost in shipment. Inspection of containers of radioactive material and accompanying documents is required promptly after receipt to monitor compliance. Receivers must report even minor discrepancies from detailed shipping regulations to the shipper, so that correction can be made in future shipments. This is done to ensure compliance with shipping regulations.

Radioactive materials shipped in the Naval Nuclear Propulsion Program include anti-contamination clothing for laundry, small sealed sources used for calibrating radiation monitoring instruments, tools and equipment used for radioactive work, low-level radioactive waste, radioactive components, and new and spent naval fuel. A total of approximately 1,000 shipments are made annually by naval nuclear-powered ships and their support facilities, which is a small part of the more than 2 million shipments of radioactive materials made annually in the United States (reference 32).

In the Naval Nuclear Propulsion Program, most radioactive shipments contain only low-level radioactivity and are classified under Department of Transportation regulations as low specific activity, surface contaminated object, or limited quantity shipments. The predominant radionuclide associated with these shipments is cobalt-60 in the form of insoluble metallic oxide corrosion products attached to surfaces of materials inside shipping containers. Most radioactive material shipments are made by truck. Air shipments are used only as necessary and are not made on passenger planes. All shipments are in accordance with Department of Transportation regulations.

Approximately one-fourth of the low-level radioactivity shipments are minute quantities in sealed instrument calibration check sources. These sources contain insignificant quantities of radioactivity, comparable to the radioactivity in typical ionization-type smoke detectors. More than half the low-level shipments are anti-contamination clothing, equipment, tools, and routine waste. The anti-contamination laundry involves shipments of special outer clothing potentially contaminated with low levels of radioactivity while worn in controlled work areas. This laundry is shipped to NRC or agreement State-licensed contractors for cleaning. On average, one shipment of low-level radioactive waste is made every two months from each Naval Nuclear Propulsion Program facility. About one-fourth of the low-level shipments are environmental and chemistry samples enroute to analytical laboratories.

The remaining few shipments are new and spent naval fuel and radioactive components associated with reactors, and these are shipped by the Department of Energy. Such shipments are made infrequently because naval nuclear-powered ships currently require at most one refueling during their service life. Measures are carried out to help safeguard these shipments and ensure they reach their destination. Each

spent naval fuel shipment is escorted by U.S. Government representatives, and each shipping container is specifically designed to withstand extreme accident impacts, to withstand fire and water immersion, and to prevent release of the material to the environment in the event of an accident. The cargo in the nuclear fuel and radioactive component shipments is non-explosive and non-flammable; in addition, the radioactive material in these components is insoluble and therefore should not be dispersed even if there were an accident.

Since 1957, all spent fuel removed from naval reactors has been shipped to the DOE's Idaho National Engineering and Environmental Laboratory (INEEL) for examination. Until 1992, naval spent fuel was reprocessed by the DOE after examination. In 1992, the DOE ceased reprocessing operations. Since then, post-examination naval spent fuel has been temporarily stored at INEEL pending the availability of a permanent repository or centralized interim storage site. Continued shipment of naval spent fuel to INEEL for examination and temporary storage was fully evaluated in a comprehensive DOE spent fuel management EIS, published in April 1995 (reference 33). (The Navy participated as a cooperating agency). Under the Record of Decision for this EIS and a court-ordered agreement among the Navy, the DOE, and the State of Idaho, naval spent fuel will continue to be shipped to INEEL through 2035 for examination, and it will be temporarily stored there until it can be shipped to a permanent geologic repository for burial or a centralized interim storage site outside Idaho for storage as soon as either facility is available.

Estimates of annual radiation exposure to transportation crews and the general public from shipments of radioactive materials in the Naval Nuclear Propulsion Program have been made in a manner consistent with that employed by the NRC in reference 32. Based on comparisons of the types and numbers of radioactive shipments made, the total annual radiation exposure to all transportation crews for all shipments is estimated to be less than 3 rem. If one person were to receive all this exposure, that person would not exceed the annual radiation exposure permitted for an individual worker by NRC. The total estimated radiation exposure accumulated by the public along transportation routes is 10 rem. The maximum exposure to any individual member of the public would be far less than that received from natural radiation.

For naval spent fuel shipments, more detailed exposure estimates are described in the DOE spent fuel management EIS cited above (reference 33) and in the Department of the Navy spent fuel container system Environmental Impact Statement published in November 1996 (reference 34). The analyses described in these EISs demonstrate that for the 744 container shipments of spent fuel made through the end of 2002, the total collective population dose is about 3 rem.

Shipments of radioactive materials associated with naval nuclear propulsion plants have not resulted in any measurable release of radioactivity to the environment. There have never been any significant accidents involving release of radioactive material during shipment since the Naval Nuclear Propulsion Program began. In general, the few accidents that have occurred involved incidents such as broken truck

axles or slight external damage to a shipping container with no release of radioactivity. In one incident, a train collision resulted in minor denting of a new fuel shipping container; despite this damage, there was no loss of integrity of the container, no damage to the fuel, and no release of radioactivity. In the only two instances that involved loss of contents, 1-quart containers holding samples with small amounts of radioactivity were broken in shipment. In one case, this occurred when a cargo aircraft crashed. The other container was lost from a commercial ship. Both containers were recovered, and there was no measurable radioactivity released since the original contents were less than a microcurie.

The requirements of the Naval Nuclear Propulsion Program specify that the carriers for all radioactive material shipments shall have accident plans that identify the actions to be taken in case the transportation vehicle is involved in an accident. These plans provide for notification of civil authorities and the originating facility. Also provided is a 24-hour telephone number at the originating facility for emergency guidance and assistance. The U.S. Navy would communicate with and cooperate fully with State radiological officials in the event of occurrences involving shipments of radioactive materials.

ENVIRONMENTAL MONITORING

To provide additional assurance that procedures used by the U.S. Navy to control radioactivity are adequate to protect the environment, the Navy conducts environmental monitoring in harbors frequented by its nuclear-powered ships. Environmental monitoring surveys for radioactivity are periodically performed in harbors where U.S. naval nuclear-powered ships are built or overhauled and where these ships have home ports or operating bases. Samples from each harbor monitored are also checked at least annually by a DOE laboratory to ensure analytical procedures are correct and standardized. The DOE laboratory findings have been consistent with those of the shipyards.

Navy Environmental Monitoring Program

The Navy environmental monitoring program consists of analyzing samples of harbor sediment, water, and marine life, supplemented by shoreline surveys, dosimeters, and effluent monitoring. Sampling harbor sediment and water each quarter is emphasized because these materials would be the most likely affected by releases of radioactivity.

As discussed earlier, cobalt-60 is the predominant radionuclide of environmental interest resulting from naval nuclear reactor operations. Therefore, Navy monitoring procedures require collecting in each harbor approximately 10 to 100 sediment samples once each quarter for analysis to detect cobalt-60 and other gamma-emitting radionuclides. Locations and numbers of sediment samples for a particular harbor depend on the size of the harbor and the number and separation of locations where

nuclear-powered ships berth. Sampling points are selected to form a pattern around ship berthing locations and to provide points in areas away from these berthing locations. The sampling locations selected are based on the individual characteristics of each harbor.

Sediment samples are collected using a dredge that samples a surface area of 36 square inches and has been modified to collect only the top layer of sediment (about an inch). The top layer was selected because it should be more mobile and more accessible to marine life than deeper layers. The samples are drained of excess water and put directly into a Marinelli container for analysis. Each sediment sample is analyzed for gamma radioactivity in the container in which it is collected, using a solid-state germanium detector with a multichannel analyzer. The gamma data are analyzed specifically for the presence of cobalt-60. Results of the sediment samples from harbors monitored by the Navy in the U.S. and its possessions are summarized in Table 2.

Table 2 shows that most harbors do not have detectable levels of cobalt-60. As reported in the past, low levels of cobalt-60, less than 3 picocuries per gram, have been detected around a few operating base and shipyard piers where nuclear-powered ship maintenance and overhauls were conducted in the early 1960s. These low levels are well below the naturally occurring radioactivity levels in the harbors. The radioactivity detected is from operations in the early 1960s. As discussed previously, from 1971 to 2002 the total long-lived gamma radioactivity released each year within 12 miles from shore from all U.S. naval nuclear-powered ships and their support facilities has been less than 0.002 curie. This low release amount is too small to be detectable in the harbors. A measure of the significance of these low levels is that if all of a person's food (reference 35) were to contain 3 picocuries of cobalt-60 per gram, that person would receive less than 10 percent of the dose from natural background radiation (see reference 19). Cobalt-60 is not detectable in general harbor bottom areas away from these piers.

Low levels of cesium-137 were detected in some sediment samples. The cesium-137 detected is not related to naval nuclear reactor operations, because the high integrity naval fuel retains fission products. The cesium-137 concentrations measured in the sediment are due to worldwide dispersion from weapons testing.

For comparison, references 36 and 37 contain evaluations by laboratories of the Georgia Department of Natural Resources and the Environmental Protection Agency of the effects on the environment from the accumulation of radionuclides near points of discharge from several nuclear facilities. The referenced reports conclude that radioactivity levels much greater than those shown in Table 2 for Naval Nuclear Propulsion Program facilities have caused no significant radiation exposure to the general public.

The maximum total radioactivity observed in a U.S. harbor is less than 0.01 curie of cobalt-60. This radioactivity is small compared to background. Based on the typical

concentrations of naturally occurring radioactivity such as potassium-40, radium, uranium, and thorium (which are described in reference 17 for marine sediment), the natural radioactivity in the sediment of a typical harbor amounts to hundreds of curies.

In addition to Navy analysis of environmental samples, at least nine sediment samples from each harbor monitored have been sent each year to a Department of Energy laboratory, as a check of Navy results. This Department of Energy laboratory provides a further check on the quality of environmental sample analyses by participating in the quality control programs sponsored by the Department of Energy Environmental Measurements Laboratory.

The check samples were analyzed for gamma radionuclides in a manner similar to Navy procedures but with greater sensitivity. Figure 3 depicts the gamma spectra for two such samples. Both spectra show the presence of abundant, naturally occurring radionuclides which contribute to measured radioactivity even if cobalt-60 were not present. The upper spectrum is for a sample to which cobalt-60 has been added to achieve a concentration of approximately 3 picocuries per gram and shows easily recognizable energy peaks due to the presence of this small concentration of cobalt-60. The lower spectrum is typical of most of the sediment samples with no detectable cobalt-60.

At least five water samples are taken in each harbor once each quarter in areas where nuclear-powered ships berth, as well as from upstream and downstream locations. These samples are analyzed for presence of gamma-emitting radionuclides, including cobalt-60. A solid-state germanium detector with a multichannel analyzer is used to measure gamma radioactivity and detect the presence of cobalt-60. Procedures for analysis will detect cobalt-60 if its concentration exceeds the Environmental Protection Agency drinking water limits of reference 15. No cobalt-60 has been detected in any of the water samples taken from any of the harbors monitored.

An Environmental Protection Agency evaluation in reference 38 shows that the cobalt-60 from naval nuclear propulsion plants is in the form of metallic corrosion product particles which do not appear to be concentrated in the food chain. However, samples of marine life such as mollusks, crustaceans, and marine plants have been collected from all harbors monitored. Marine life samples are also analyzed using a germanium detector with a multichannel analyzer. The results of the marine life samples from harbors monitored by the Navy in the U.S. and possessions are summarized in Table 3. Table 3 demonstrates that no buildup of cobalt-60 associated with U.S. naval nuclear-powered ships has been detected in these samples of marine life.

Table 2: Summary of 2002 Surveys for Cobalt-60 in Bottom Sediment of U.S. Harbors Where U.S. Naval Nuclear-Powered Ships Have Been Regularly Based, Overhauled, or Built

Facility	Range of Cobalt-60 Analytical Results (pCi/gm)	Number of Samples with Cobalt-60		Total Bottom Area with Cobalt-60 greater than 3 pCi/gm (square kilometers)
		less than 3 pCi/gm	greater than 3 pCi/gm	
Kittery, Maine Portsmouth Naval Shipyard	<0.02 – <0.05	120	0	0
Groton, New London, Connecticut Electric Boat Division, Naval Submarine Base	<0.04 – <0.10	384	0	0
Newport News, Virginia Newport News Shipbuilding	<0.02 – <0.03 0.022(4)	188	0	0
Norfolk, Virginia Naval Shipyard and Station	<0.02 – <0.05	280	0	0
Charleston, South Carolina Naval Nuclear Power Training Unit	<0.01 – <0.02	36	0	0
Kings Bay, Georgia	<0.01 – <0.03	101	0	0
San Diego, California Navy Bases	<0.01 –<0.05	252	0	0
Puget Sound, Washington Naval Shipyard and Bases	<0.01 – <0.05	392	0	0
Pearl Harbor, Hawaii Naval Shipyard and Intermediate Maintenance Facility	<0.01 – <0.08(5)	208	0	0
Apra Harbor, Guam	<0.01 – <0.03	108	0	0
Port Canaveral, Florida	<0.01 – <0.03	80	0	0

NOTES:

(1) The less-than symbol [<] indicates that no cobalt-60 was detected in the sample. The number given is the minimum detectable concentration (MDC); i.e., the concentration at which cobalt-60 could be detected if it were present. The MDC varies from sample to sample and location to location due to differences in the amount of naturally occurring radioactivity in each sample, differences in the weight of the sample, detection equipment differences, and statistical fluctuations.

(2) pCi/gm = picocurie per gram. 1 pCi = $1x10^{-12}$ curie (Ci).

(3) One square kilometer is approximately 0.4 square mile. Estimated total cobalt-60 in the top layer of sediment is 0.01 Ci. Samples from more than one foot deep from several harbors show that cobalt-60 present may be two to five times that measured in the surface layer.

(4) One sample had a detectable concentration of cobalt-60 of 0.022 pCi/gm.

(5) Samples in addition to the normal environmental monitoring program were taken in April and May 2002. Of the 25 additional samples, only one had detectable cobalt-60. This sample had a cobalt-60 concentration of 0.087 pCi/gm.

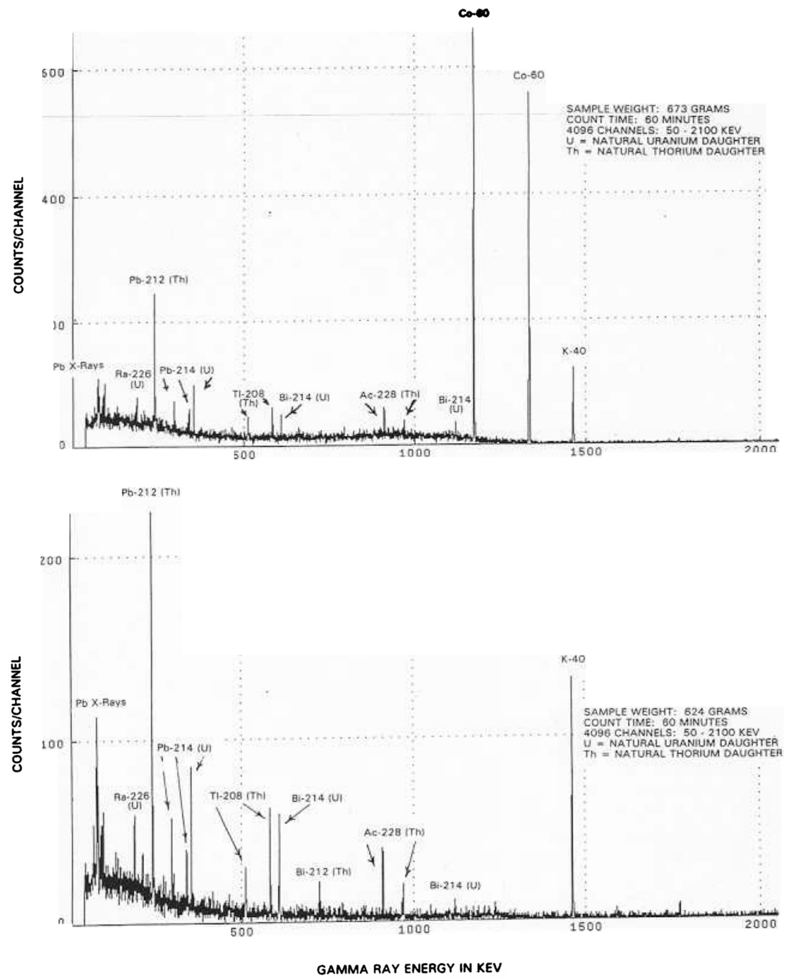


Figure 3:
Gamma Spectra of Harbor Bottom Sediment Samples
with a Germanium Detector

In all monitored harbors, shoreline areas uncovered at low tide are surveyed twice per year for radiation levels, using sensitive scintillation detectors to determine if any radioactivity from bottom sediment washed ashore. All results were the same as background radiation levels in these regions, approximately 0.01 millirem per hour. Thus, there is no evidence in these ports that these areas are being affected by the operation of nuclear-powered ships.

Ambient radiation levels are continuously measured using sensitive thermoluminescent dosimeters posted at locations outside the boundaries of areas where radiological work is performed. These dosimeters are also posted at locations remote from support facilities to measure background radiation levels from natural radioactivity. The results of dosimeters posted at support facilities between radiologically controlled areas and the general public and dosimeters posted at remote background locations up to several miles away are compared in Table 4. The range of dosimeter readings is also given: natural background radiation levels vary from location to location primarily due to the concentration of radionuclides in the soil (reference 19). Table 4 shows that Naval Nuclear Propulsion Program activities had no distinguishable effect on normal background radiation levels at the site perimeter.

Naval nuclear reactors and their support facilities are designed to ensure that there are no significant discharges of radioactivity in airborne exhausts. Radiological controls are exercised in support facilities to preclude exposure of working personnel to airborne radioactivity exceeding one-tenth of the limits specified in reference 7. These controls, discussed in reference 28, include containment for radioactive materials and provide a barrier to prevent significant radioactivity from becoming airborne. Further, all air exhausted from these facilities is passed through high efficiency particulate air (HEPA) filters and monitored during discharge. Comparison of sensitive airborne radioactivity measurements in shipyards demonstrates that air exhausted from facilities actually contained a smaller amount of particulate radioactivity than it did when it was drawn from the environment.

Table 3: Summary of 2002 Surveys for Cobalt-60 in Marine Life of U.S. Harbors Where U.S. Naval Nuclear-Powered Ships Have Been Regularly Based, Overhauled, or Built

Facility	Mollusks	Crustaceans	Marine Plants
	Cobalt-60 Analytical Results (pCi/gm)	Cobalt-60 Analytical Results (pCi/gm)	Cobalt-60 Analytical Results (pCi/gm)
Kittery, Maine Portsmouth Naval Shipyard	<0.040	<0.038	<0.045
Groton, New London, Connecticut Electric Boat Division, Naval Submarine Base	<0.068	<0.059	<0.080
Newport News, Virginia Newport News Shipbuilding	<0.022	<0.019	<0.021
Norfolk, Virginia Naval Shipyard and Station	<0.028	<0.031	<0.038
Charleston, South Carolina Naval Nuclear Power Training Unit	<0.013	<0.007	Not Applicable
Kings Bay, Georgia	<0.012	<0.011	<0.012
San Diego, California Navy Bases	<0.038	<0.032	<0.012
Puget Sound, Washington Naval Shipyard and Bases	<0.049	<0.037	<0.067
Pearl Harbor, Hawaii Naval Shipyard and Intermediate Maintenance Facility	Not Applicable	<0.071	<0.051
Apra Harbor, Guam	<0.012	<0.010	<0.011
Port Canaveral, Florida	<0.012	<0.010	<0.012

NOTES:

(1) The less-than symbol [<] indicates that no cobalt-60 was detected in the sample. The number given is the minimum detectable concentration (MDC); i.e., the concentration at which cobalt-60 could be detected if it were present. The MDC varies from sample to sample and location to location due to differences in the amount of naturally occurring radioactivity in each sample, differences in the weight of the sample, detection equipment differences, and statistical fluctuations.

(2) pCi/gm = picocurie per gram. 1 pCi = 1×10^{-12} curie (Ci)

Table 4: Summary of 2002 Off-Site and Perimeter Radiation Monitoring of U.S. Harbors Where U.S. Naval Nuclear-Powered Ships Have Been Regularly Based, Overhauled or Built

FACILITY	Average Off-site Dosimeter (mrem/qtr)	Range of Off-site Dosimeter (mrem/qtr)	Average Perimeter Dosimeter (mrem/qtr)	Range of Perimeter Dosimeter (mrem/qtr)
Kittery, Maine Portsmouth Naval Shipyard	19	17 – 22	20	14 – 23
Groton, New London, Connecticut Electric Boat Division, Naval Submarine Base	28	24 – 36	27	19 – 35
Newport News, Virginia Newport News Shipbuilding	14	9 – 24	14	10 – 23
Norfolk, Virginia Naval Shipyard and Station	26	19 – 33	19	11 – 31
Charleston, South Carolina Naval Nuclear Power Training Unit	15	10 – 22	17	10 – 20
Kings Bay, Georgia	20	14 – 37	22	15 – 30
San Diego, California Navy Bases	26	19 – 32	21	14 – 30
Puget Sound, Washington Naval Shipyard and Bases	17	13 – 20	17	13 – 19
Pearl Harbor, Hawaii Naval Shipyard and Intermediate Maintenance Facility	21	19 – 26	20	14 – 24
Apra Harbor, Guam	18	14 – 22	18	11 – 29
Port Canaveral, Florida	18	11 – 25	19	12 – 24

NOTES:
(1) mrem/qtr = millirem per quarter year. 1 mrem = $1x10^{-3}$ rem.

24

ENVIRONMENTAL PATHWAYS ANALYSIS

Results of monitoring of environmental samples described above show that environmental radioactivity levels have not changed appreciably; therefore, radiation exposure to the public from operations of nuclear-powered ships and their support facilities is too low to measure. Nevertheless, an analysis has been performed to provide a quantitative estimate of the radiation to which any member of the general public might be exposed as a result of radioactivity in liquid and airborne effluents.

For analysis of airborne effluents, the EPA COMPLY computer program is used, as required by EPA regulations in reference 39. Site-specific input parameters include radionuclide releases, distance to members of the public, wind speed and direction, and food production. The releases of airborne effluents used in the analysis are summarized in Table 5. Cobalt-60 values include actual measurements of cobalt-60 emissions from the exhaust of Navy facilities, in addition to estimates of other potential sources of cobalt-60. Estimated values for other airborne radionuclides are based upon detailed study of land-based naval nuclear propulsion prototype plants, nuclear-powered ships, and their support facilities.

Results of the airborne effluent analysis are summarized in Table 6. Table 6 compares the estimated maximum exposure to a member of the public from Program effluents with guidelines of the NRC in reference 14. These numerical guidelines on calculated radiation exposures implement the concept that radioactivity in effluents from light water nuclear electric power reactors should be limited to amounts and quantities as low as reasonably achievable. Although these guidelines are not applicable to nuclear-powered ships and their support facilities, they provide a context in which to judge the significance of radiation exposures from Program effluents. The estimated maximum radiation exposure to a member of the general public from releases of airborne radioactivity is also much less than the standard of 10 millirem per year established by the EPA in reference 39.

Table 5: Radionuclide Releases Used for Environmental Pathways Analysis

Radionuclide	Annual Airborne Release (Curies)
Cobalt-60*	<0.0004
Tritium*	<1.5
Carbon-14*	<20
Krypton-83m	0.011
Krypton-85m	0.027
Krypton-85	0.000023
Krypton-87	0.035
Krypton-88	0.055
Xenon-131m	0.0015
Xenon-133m	0.012
Xenon-133	0.30
Xenon-135	0.33
Argon-41	3.3
Iodine-131	0.0000050
Iodine-132	0.0000054
Iodine-133	0.000014
Iodine-135	0.0000097

* Site-specific values are used for these radionuclides. The tabulated values bound the site-specific values used in the analysis.

For liquid effluents, the results of the environmental monitoring samples demonstrate, without the need for any detailed theoretical model calculations, that there is no significant radiation exposure to members of the public. For example, the samples of marine life obtained from the immediate vicinity of shipyard piers and drydocks did not have any detectable cobalt-60, even with sensitive analysis. Even if cobalt-60 were assumed to be present at concentrations just below the limits of detection shown in Table 5 and a person were to eat 40 pounds per year of mollusks and crustaceans caught directly from these areas, the person would receive much less than one millirem per year. Similarly, even though the Navy minimizes releases of radioactive liquids and there has never been any detectable cobalt-60 in harbor water, the water consumption pathway cannot result in any dose to the public since seawater is not used for drinking water consumption in the vicinity of these facilities. Thus, exposures to members of the public from the Naval Nuclear Propulsion Program liquid effluents are far less than the guidelines of the NRC, which are listed in Table 6.

Table 6: Estimated Maximum Radiation Exposure to an Individual for Assumed Liquid Releases and Airborne Radioactivity Releases from Shipyards Engaged in Naval Nuclear Propulsion Work

SOURCE	Maximum Exposure to an Individual	
	NRC Guideline (millirem/year)	Estimated Value (millirem/year)
From Radionuclides in Liquid Releases	3 whole body, or 10 any organ	< 1
From Gaseous Radionuclides in Airborne Releases	5 whole body, or 15 skin	< 1
From Other Radionuclides in Airborne Releases	15 any organ	< 1

SOURCE	Maximum Exposure to an Individual	
	EPA Regulation (effective whole body, millirem/year)	Estimated Value (effective whole body, millirem/year)
From Radioiodine in Airborne Releases	3	< 0.03
From Other Radionuclides in Airborne Releases	10	< 1

AUDITS AND REVIEWS

The requirements and procedures for control of radioactivity is an important part of the training programs for everyone involved with radioactivity in the Naval Nuclear Propulsion Program. Such training is part of the initial qualification of shipyard workers and of naval personnel assigned to ships and bases, and is required to be repeated regularly. Emphasis on this training is part of the concept that radiological control personnel alone cannot always cause radiological work to be well performed; production and operations personnel and all levels of management must be involved in the control of radioactivity.

Checks and balances of several kinds are also set up to help ensure control of radioactivity. Written procedures exist that require verbatim compliance. Radiological control personnel monitor various steps in radioactive waste processing. In each shipyard, an independent organization, separate from the radiological control organization, audits all aspects of radioactive waste processing. Audits are performed by representatives from Naval Reactors Headquarters who are assigned full-time at each shipyard. Radiological control personnel from Headquarters also conduct periodic inspections of each shipyard. In addition, shipyards have made detailed assessments of the environmental effects of shipyard operations and have published reports on the results of these assessments. Similarly, there are multiple levels of audits and inspections for the other Navy shore facilities, tenders, and nuclear-powered ships, as well as for other radiologically controlled functions (such as transportation). Even the smallest audit findings are followed up to ensure proper recovery and permanent corrective actions are taken and to help minimize the potential for future deficiencies.

The policy of the Navy is to provide for close cooperation and effective communication with State radiological officials whenever there are occurrences that might cause concern because of radiological effects outside the ships or shore facilities. The Navy has reviewed radioactive waste disposal, radiological environmental monitoring, transportation, and other radiological matters with State radiological officials in the States where Navy nuclear-powered ships are based or overhauled. Although there were no occurrences in 2002 that resulted in radiological effects to the public outside these facilities, States were notified when inquiries showed public interest in the possibility that such events had occurred. The Navy has encouraged States to conduct independent radiological environmental monitoring in harbors where naval nuclear-powered ships are based or overhauled; the States' findings have been consistent with the Navy's.

An EPA laboratory has conducted detailed environmental surveys of selected U.S. harbors (references 30 and 40-48). This laboratory has performed these surveys in the harbors at Pascagoula, Mississippi; Charleston, South Carolina; Pearl Harbor, Hawaii; San Diego, Alameda, San Francisco, and Vallejo, California; New London and Groton, Connecticut; Newport News, Portsmouth, and Norfolk, Virginia; Kings Bay, Georgia; Kittery, Maine / Portsmouth, New Hampshire; and Bremerton and Bangor, Washington. EPA findings have been consistent with those of the Navy, and have concluded that operation of naval nuclear-powered ships has had no adverse impact on public safety or health.

CONCLUSIONS

1. The total long-lived gamma radioactivity in liquids released into all ports and harbors from the Naval Nuclear Propulsion Program was less than 0.002 curie in 2002. For perspective, 0.002 curie is less than the quantity of naturally occurring radioactivity in the volume of saline harbor water occupied by a single submarine.

2. No increase of radioactivity above normal background levels has been detected in harbor water during Navy and EPA monitoring of harbors where U.S. naval nuclear-powered ships are based, overhauled, or constructed.

3. Liquid releases from U.S. naval nuclear-powered ships and their support facilities have not caused a measurable increase in the general background radioactivity of the environment.

4. Low-level cobalt-60 radioactivity in harbor bottom sediment is detectable around a few operating base and shipyard piers from low-level liquid releases in the 1960s; however, these concentrations of cobalt-60 are less than the concentrations of naturally occurring radionuclides around these piers. Cobalt-60 is not detectable in general harbor bottom areas away from these piers. The maximum total radioactivity observed in a U.S. harbor, less than 0.01 curie of cobalt-60, is small compared to the naturally occurring radioactivity. Comparison to previous environmental data shows that these environmental cobalt-60 levels are decreasing.

5. Estimates of radiation exposures to members of the public from the Naval Nuclear Propulsion Program are far less than EPA environmental standards, NRC guidelines, or the exposure from natural background radioactivity.

6. Procedures used by the Navy to control releases of radioactivity from U.S. naval nuclear-powered ships and their support facilities have been effective in protecting the environment and the health and safety of the general public. Independent radiological environmental monitoring performed by the EPA and the States have confirmed the adequacy of these procedures. These procedures have ensured that no member of the general public has received measurable radiation exposure as a result of current operations of the Naval Nuclear Propulsion Program.

7. The successful radiological deactivation and closures of Ingalls Shipbuilding radiological facilities in 1982 and of Charleston and Mare Island Naval Shipyards in 1996 demonstrate that the stringent control over radioactivity exercised by the Naval Nuclear Propulsion Program from its inception has been successful in preventing radiological contamination of the environment and in avoiding expensive radiological liabilities at shipyards.

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APPENDIX

ENVIRONMENTAL MONITORING SURVEY CHARTS

Environmental monitoring survey charts for harbors monitored for radioactivity associated with U.S. naval nuclear-powered ships in the U.S. and possessions are listed below and included in this appendix. The sampling locations for harbor water and harbor sediment are shown. In addition, shoreline survey areas and the locations of posted dosimetry devices are shown on the figures.

Figure No.	Location
	California
1	U.S. Naval Air Station North Island, San Diego
2	U.S. Naval Submarine Base, San Diego
3	U.S. Naval Station, San Diego
	Connecticut
4	Electric Boat Corporation, Groton
5	U.S. Naval Submarine Support Facility, New London Harbor
	Florida
6	Port Canaveral
	Georgia
7	U.S. Naval Submarine Base, Kings Bay
	Guam
8	Apra Harbor
	Hawaii
9	Pearl Harbor Area
10	Pearl Harbor Naval Shipyard and Intermediate Maintenance Facility - Shipyard Area, Pearl Harbor
11	Pearl Harbor Naval Shipyard and Intermediate Maintenance Facility - Submarine Base Area, Pearl Harbor
	New Hampshire/Maine
12	Portsmouth Naval Shipyard

South Carolina
13 Naval Nuclear Power Training Unit,

Virginia
14 Newport News Shipbuilding,
Newport News
15 Norfolk Naval Shipyard, Portsmouth
16 U.S. Naval Station, Norfolk
17 Norfolk-Portsmouth Virginia Area

Washington
18 Puget Sound Naval Shipyard
19 Bangor/Hood Canal
20 U.S. Naval Station, Everett

FIGURE 1
ENVIROMENTAL MONITORING LOCATIONS AT
U. S. NAVAL AIR STATION NORTH ISLAND, SAN DIEGO, CA

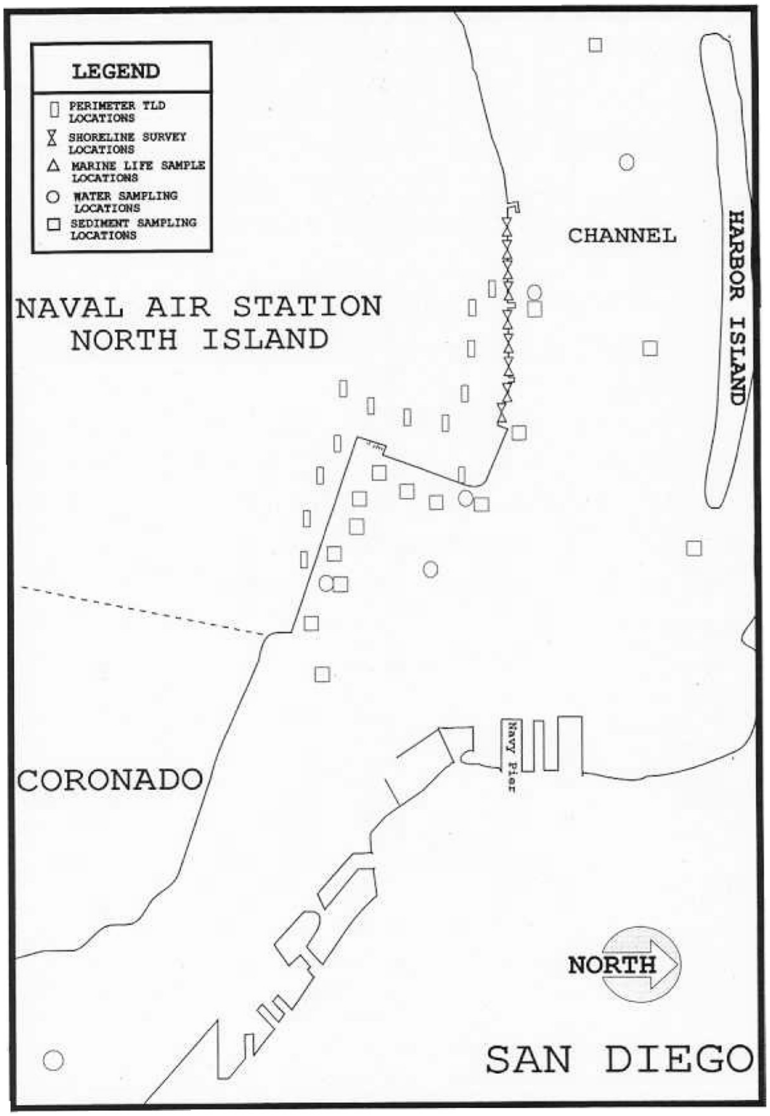


FIGURE 2
ENVIRONMENTAL MONITORING LOCATIONS AT
U. S. NAVAL SUBMARINE BASE, SAN DIEGO, CA

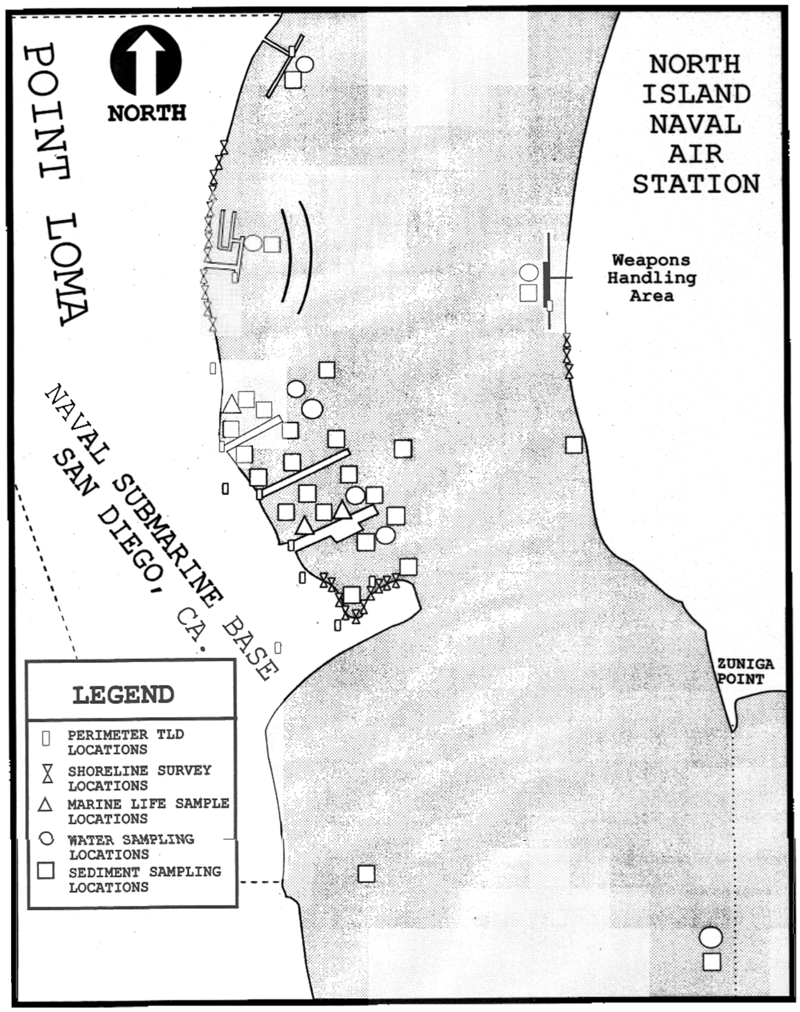


FIGURE 3
ENVIRONMENTAL MONITORING LOCATIONS AT
U. S. NAVAL STATION 32ND ST, SAN DIEGO, CA

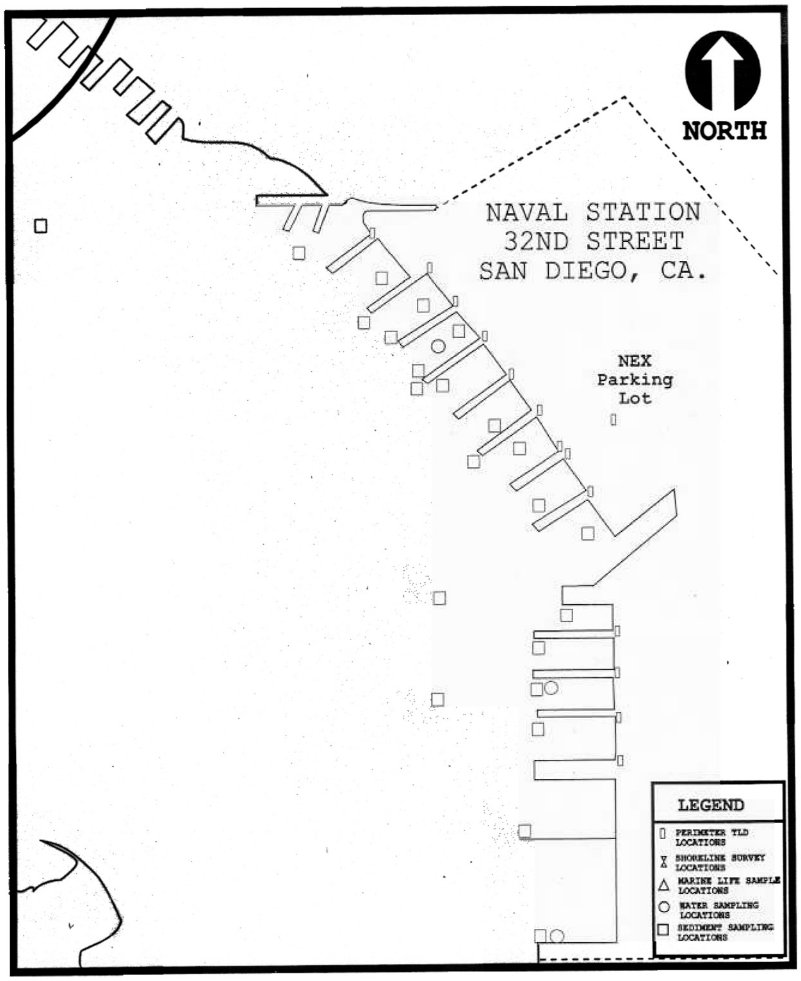


FIGURE 4
ENVIRONMENTAL MONITORING LOCATIONS AT
GENERAL DYNAMICS, ELECTRIC BOAT
GROTON, CT

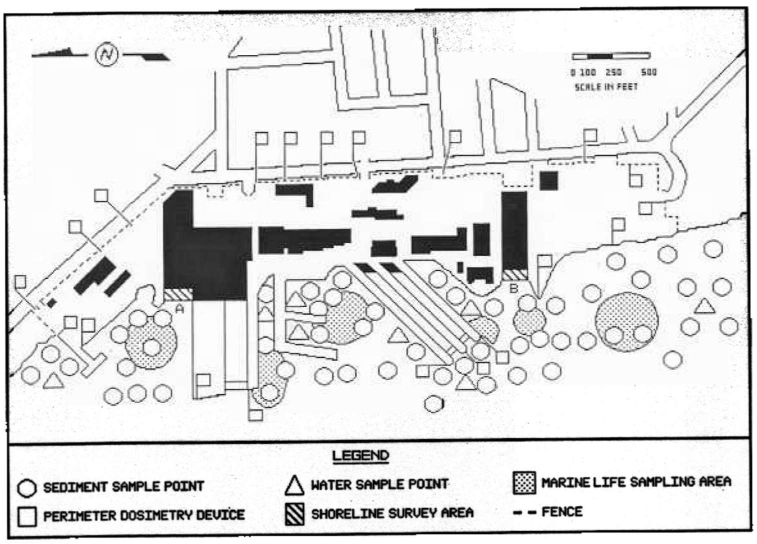


FIGURE 5
ENVIRONMENTAL MONITORING LOCATIONS AT NAVAL SUBMARINE BASE, NEW LONDON, CT.

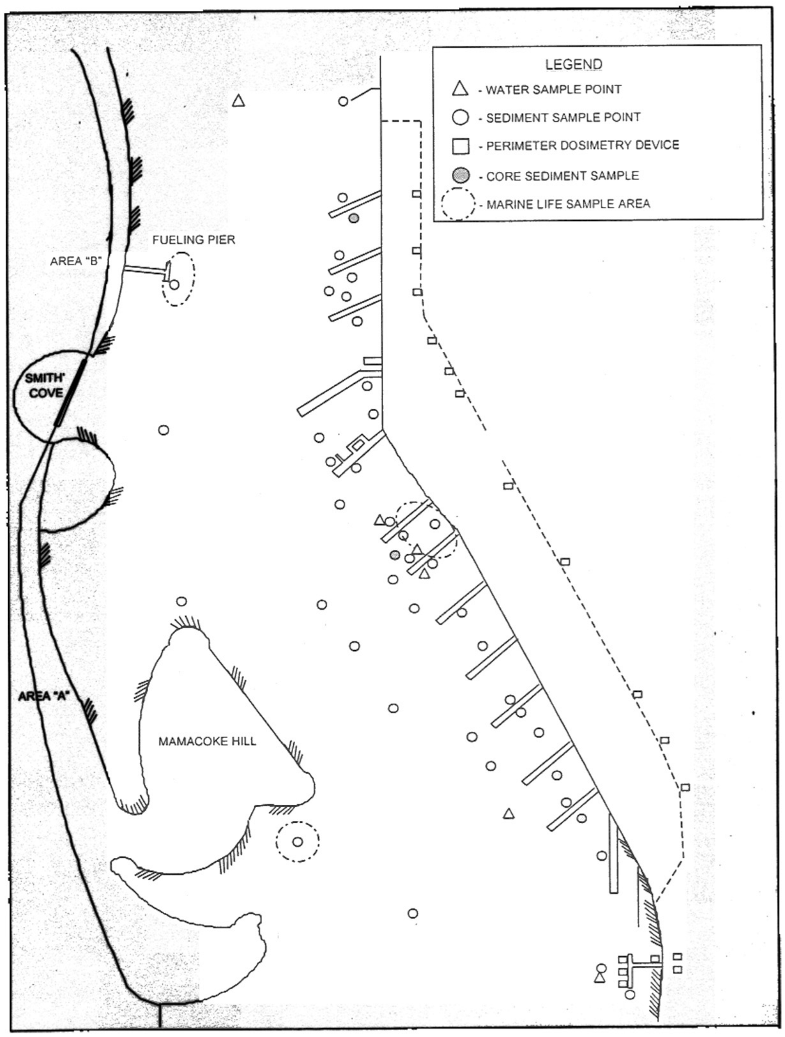
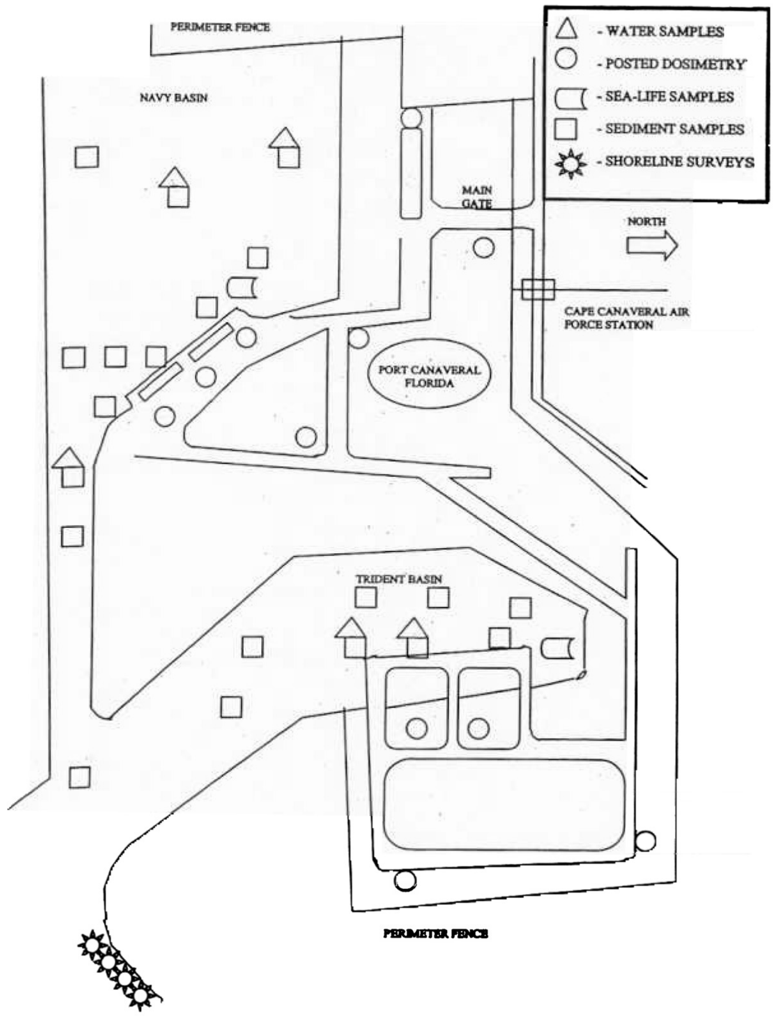


FIGURE 6
ENVIRONMENTAL MONITORING LOCATIONS AT PORT CANAVERAL, FL



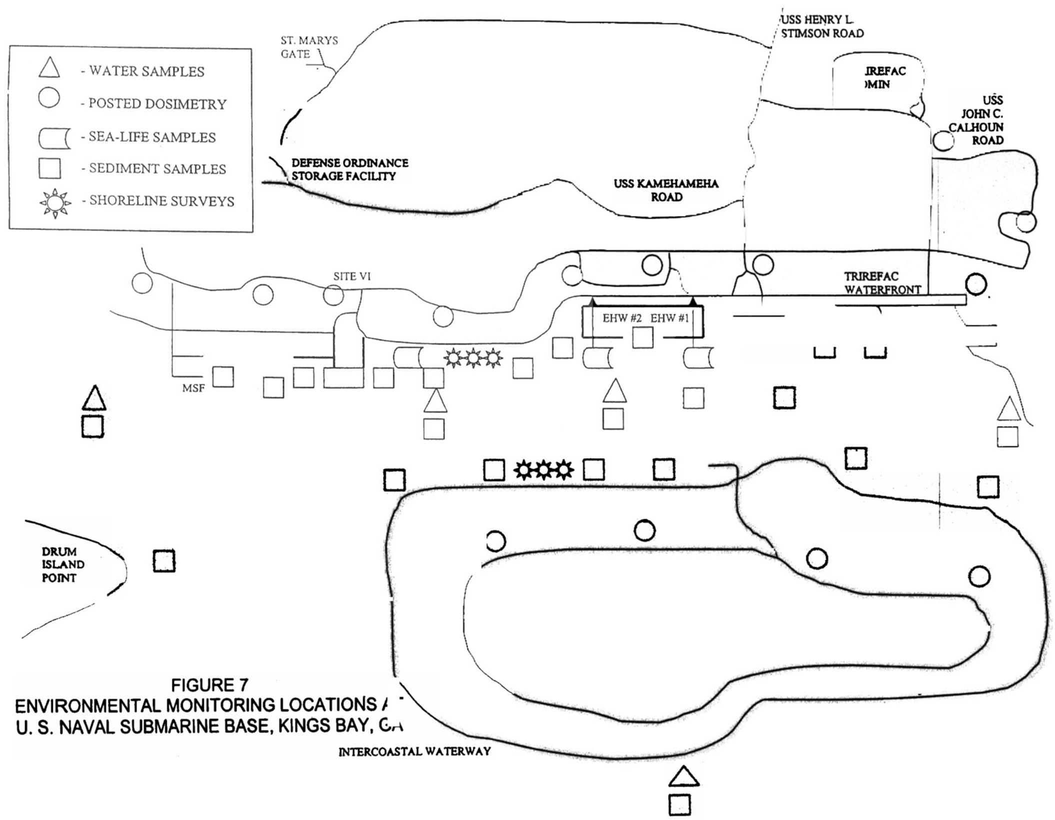


FIGURE 7
ENVIRONMENTAL MONITORING LOCATIONS A
U. S. NAVAL SUBMARINE BASE, KINGS BAY, GA

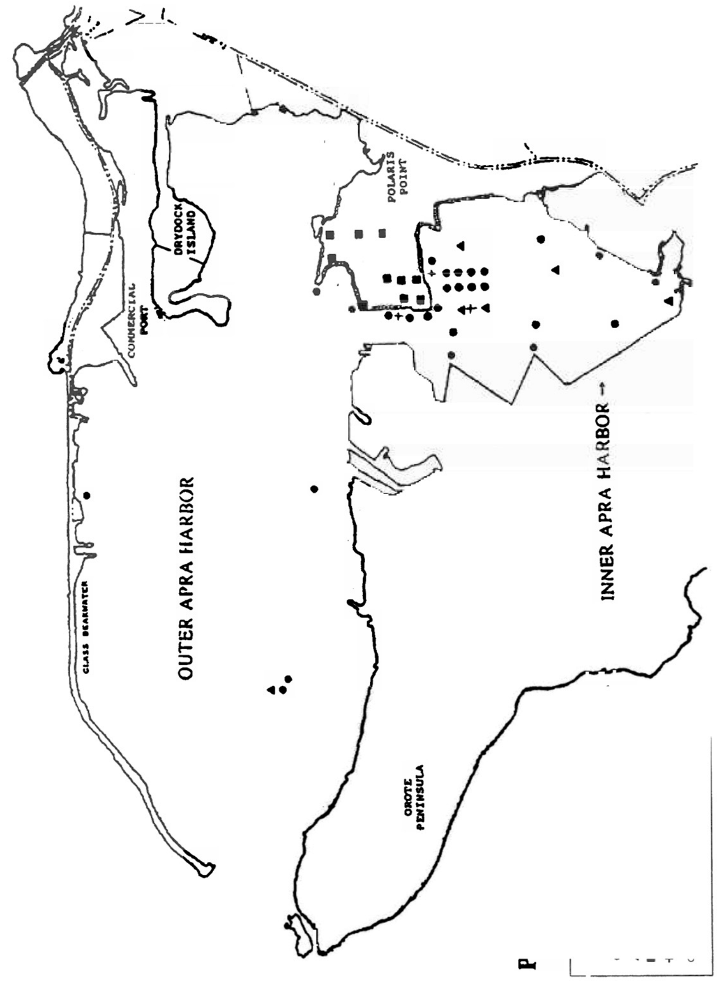


FIGURE 8
ENVIRONMENTAL MONITORING LOCATIONS AT
APRA HARBOR, GUAM

FIGURE 9
ENVIRONMENTAL MONITORING LOCATIONS AT PEARL HARBOR, HI

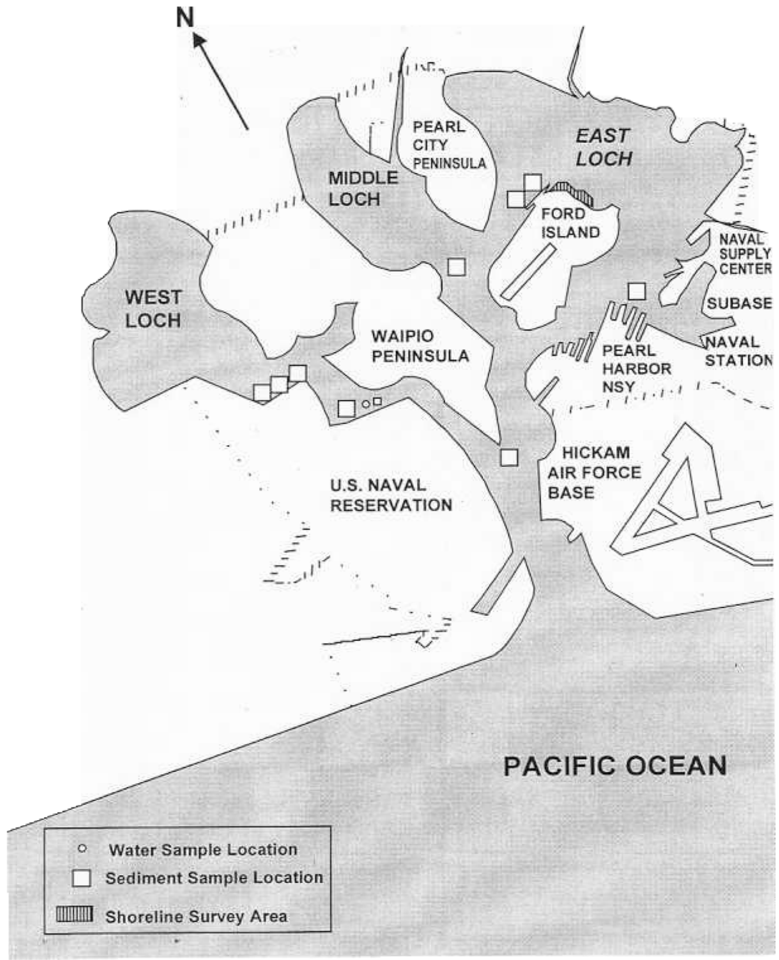


FIGURE 10
ENVIRONMENTAL MONITORING LOCATIONS AT PEARL HARBOR NAVAL SHIPYARD AND INTERMEDIATE MAINTENANCE FACILITY – SHIPYARD AREA

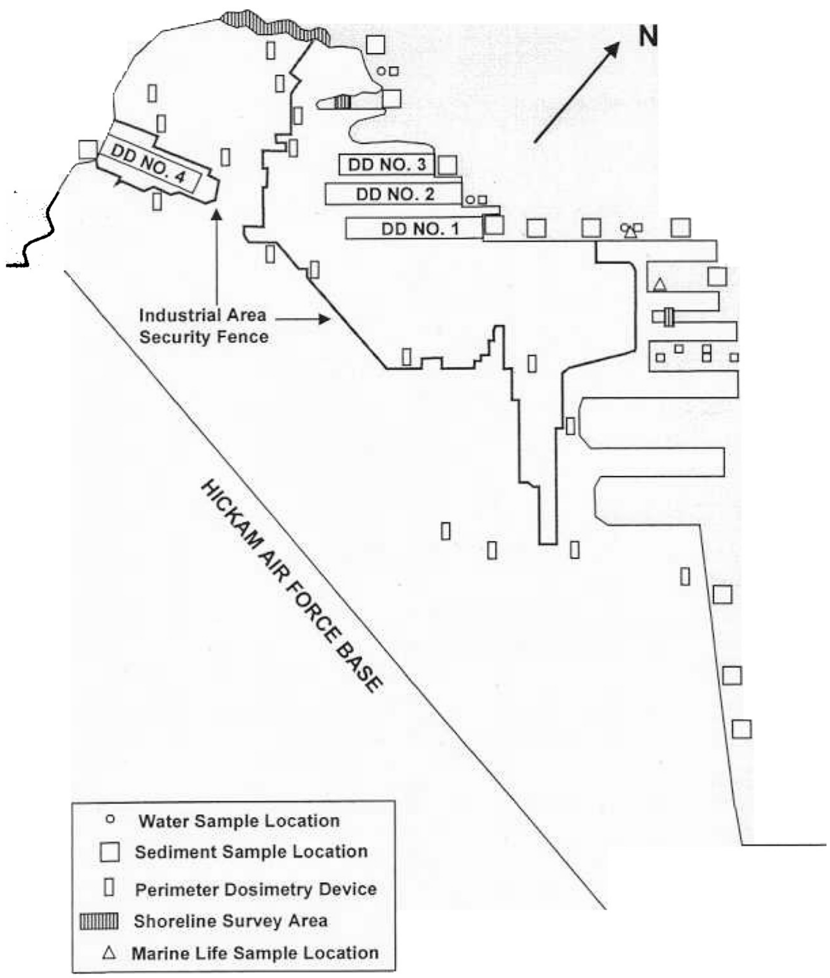


FIGURE 11
ENVIRONMENTAL MONITORING LOCATIONS AT PEARL HARBOR NAVAL SHIPYARD AND INTERMEDIATE MAINTENANCE FACILITY – SUBMARINE BASE AREA

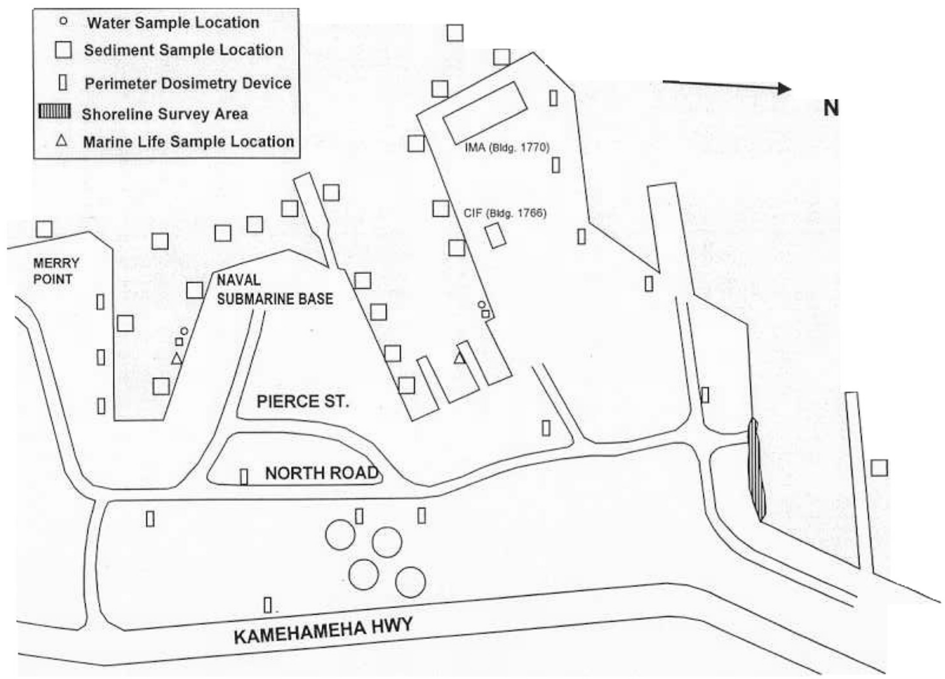


FIGURE 12
ENVIRONMENTAL MONITORING LOCATIONS AT
PORTSMOUTH NAVAL SHIPYARD
KITTERY, ME/PORTSMOUTH, NH

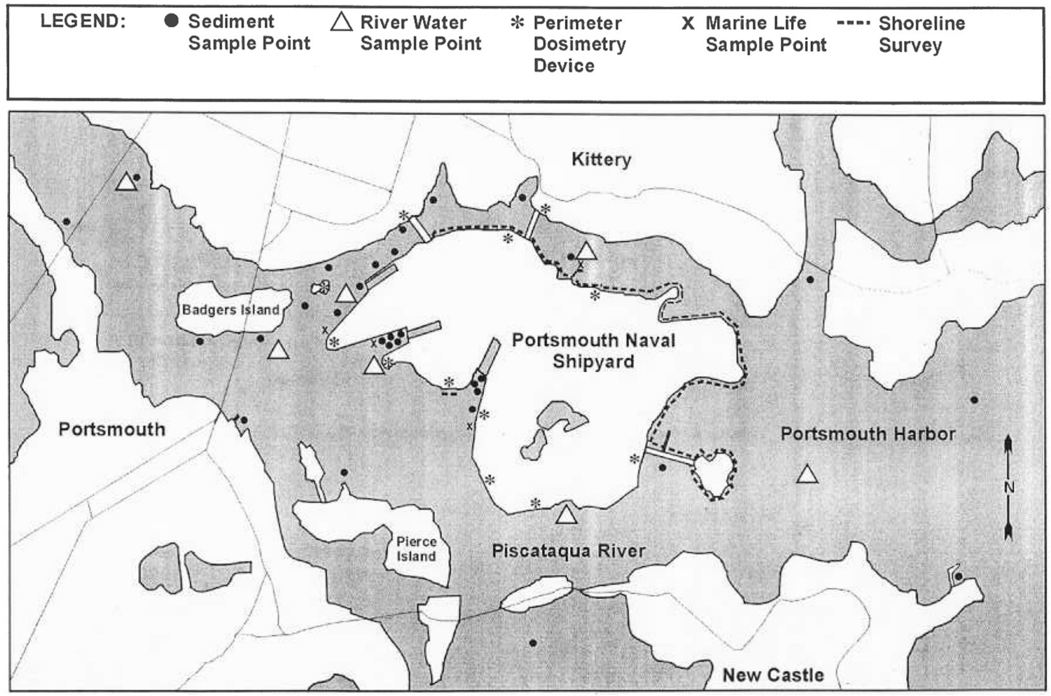


FIGURE 13
ENVIRONMENTAL MONITORING LOCATIONS AT
NAVAL NUCLEAR PROPULSION TRAINING UNIT, CHARLESTON, SC

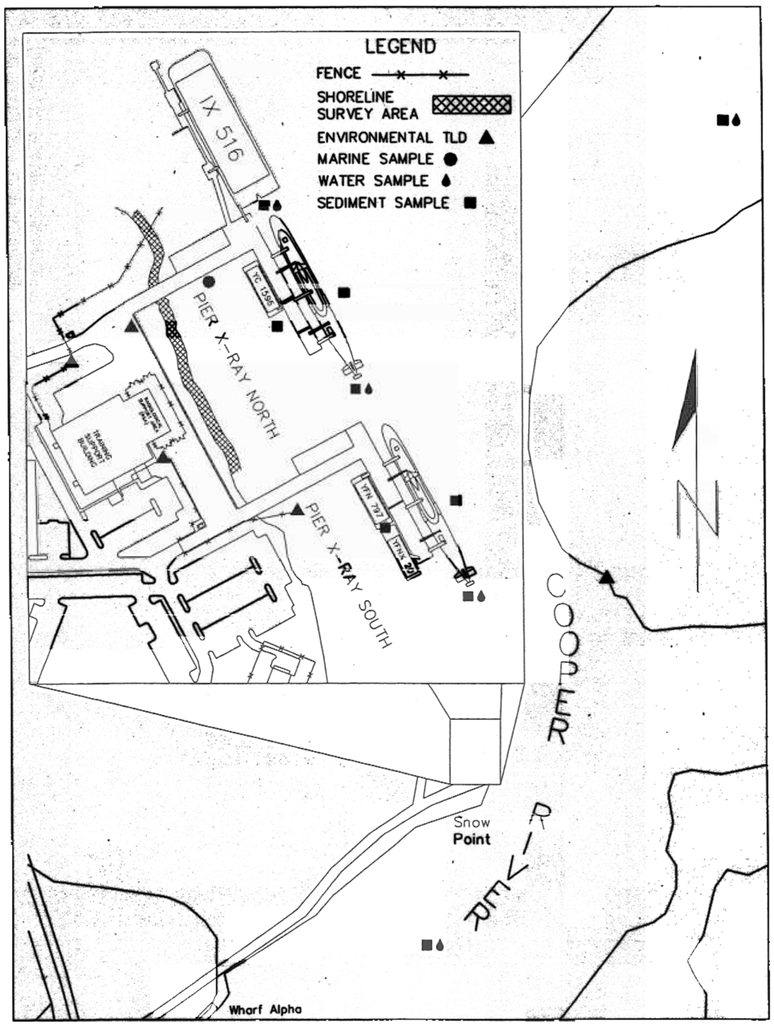


FIGURE 14
ENVIRONMENTAL MONITORING LOCATIONS AT
NORTHROP GRUMMAN NEWPORT NEWS, NEWPORT NEWS, VA

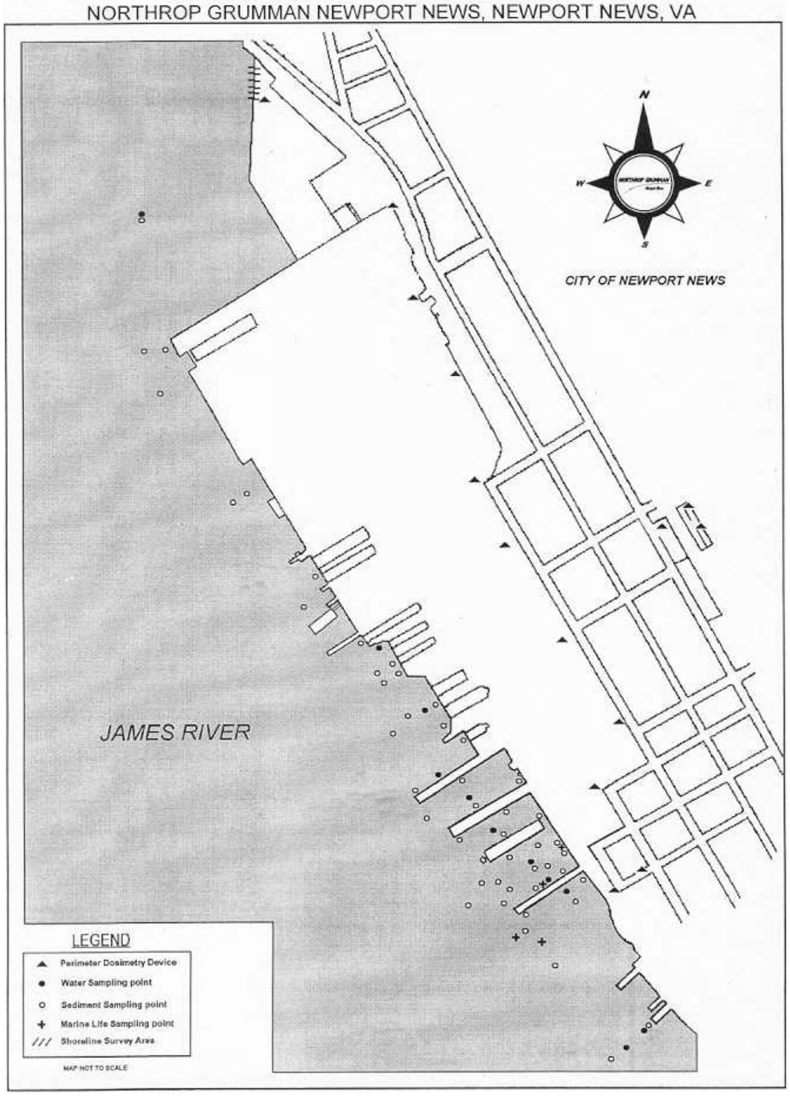


FIGURE 15
ENVIRONMENTAL MONITORING LOCATIONS AT
NORFOLK NAVAL SHIPYARD, PORTSMOUTH, VA

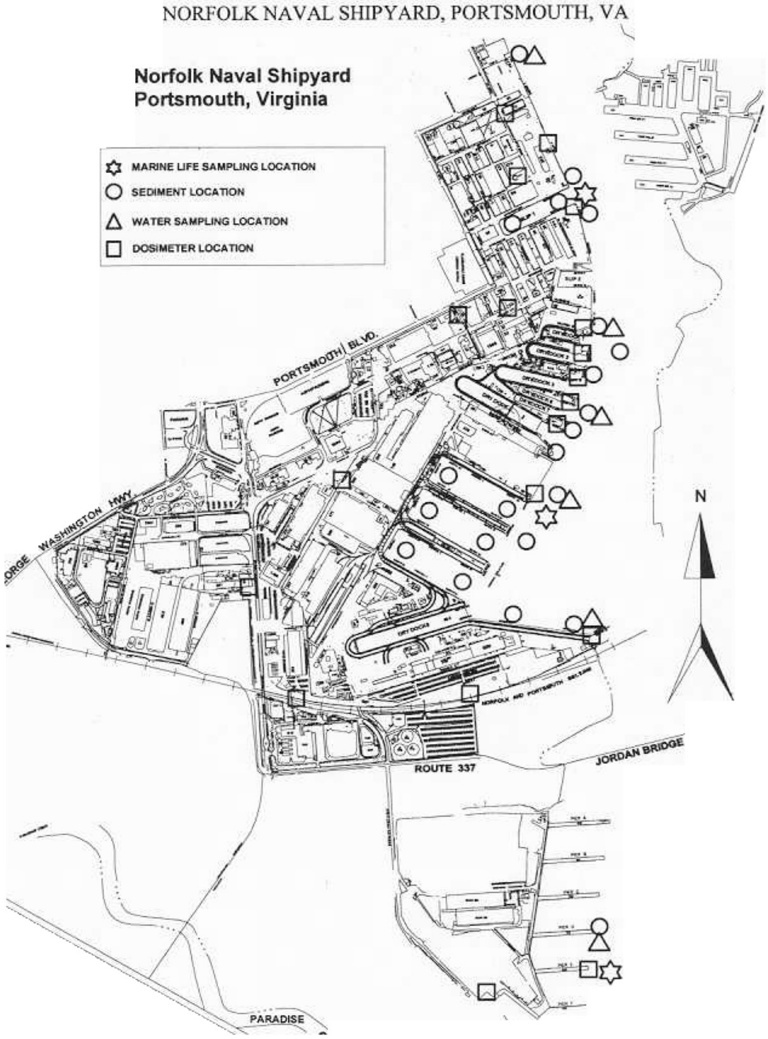
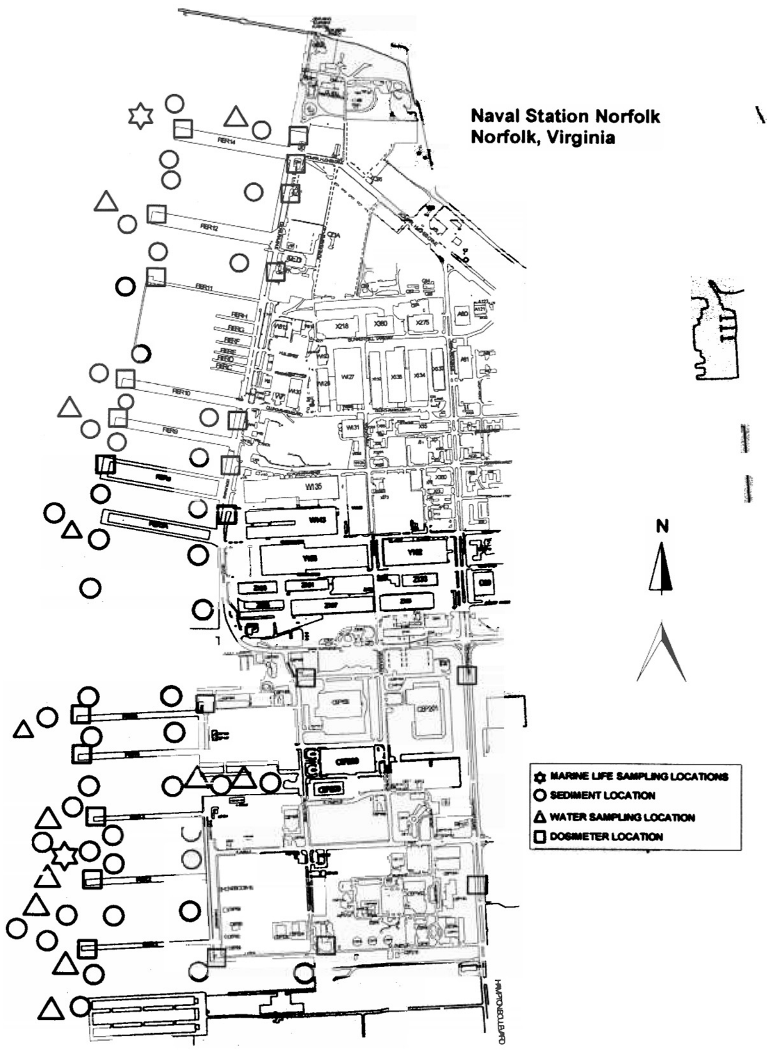


FIGURE 16
ENVIRONMENTAL MONITORING LOCATIONS AT
U. S. NAVAL STATION, NORFOLK, VA



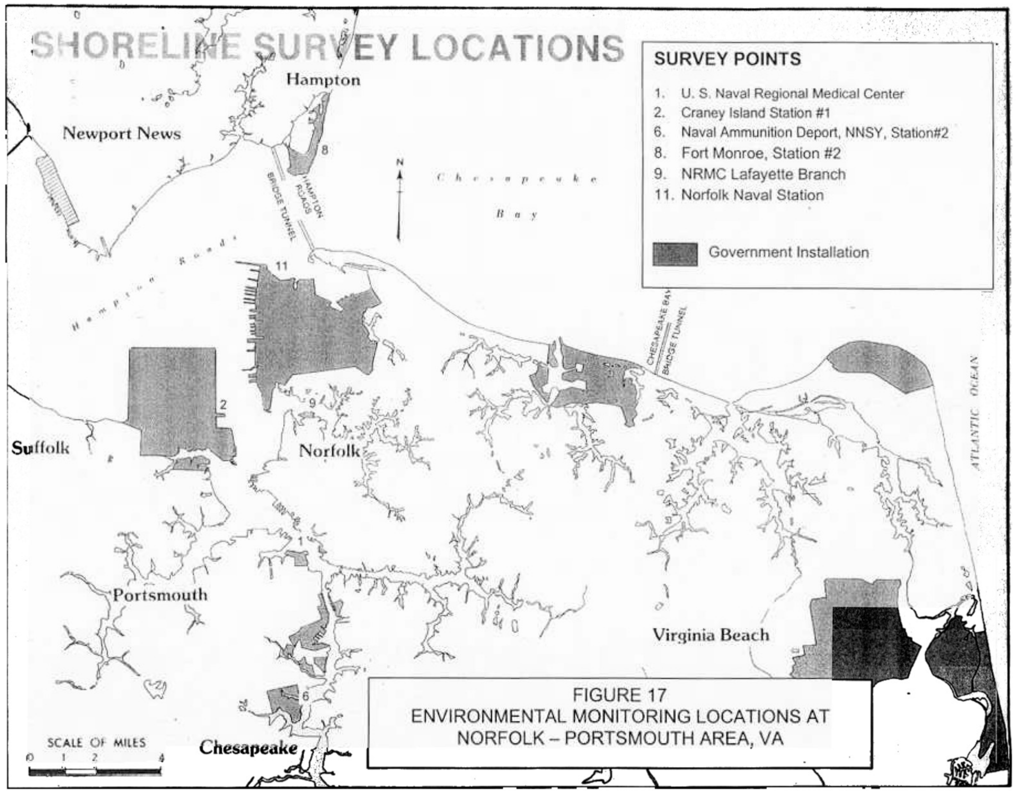


FIGURE 17
ENVIRONMENTAL MONITORING LOCATIONS AT
NORFOLK – PORTSMOUTH AREA, VA

FIGURE 18
ENVIRONMENTAL MONITORING LOCATIONS AT
PUGET SOUND NAVAL SHIPYARD, BREMERTON, WA

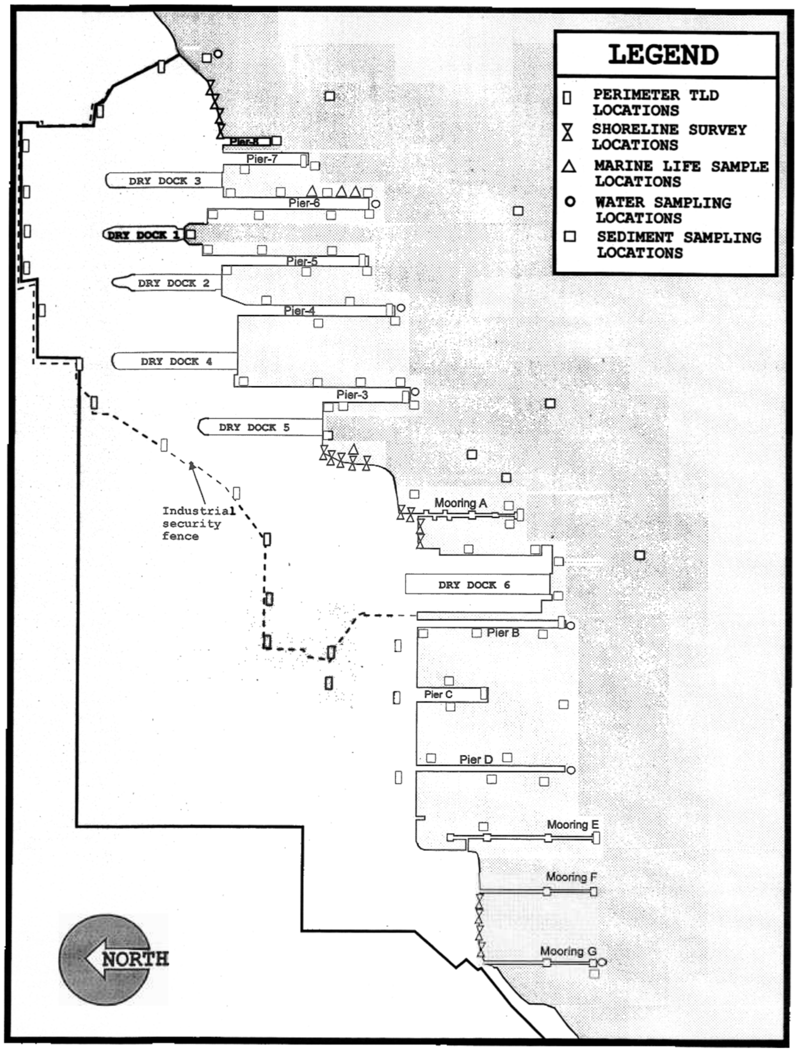


FIGURE 19
ENVIRONMENTAL MONITORING LOCATIONS AT
U. S. NAVAL SUBMARINE BASE, BANGOR, WA

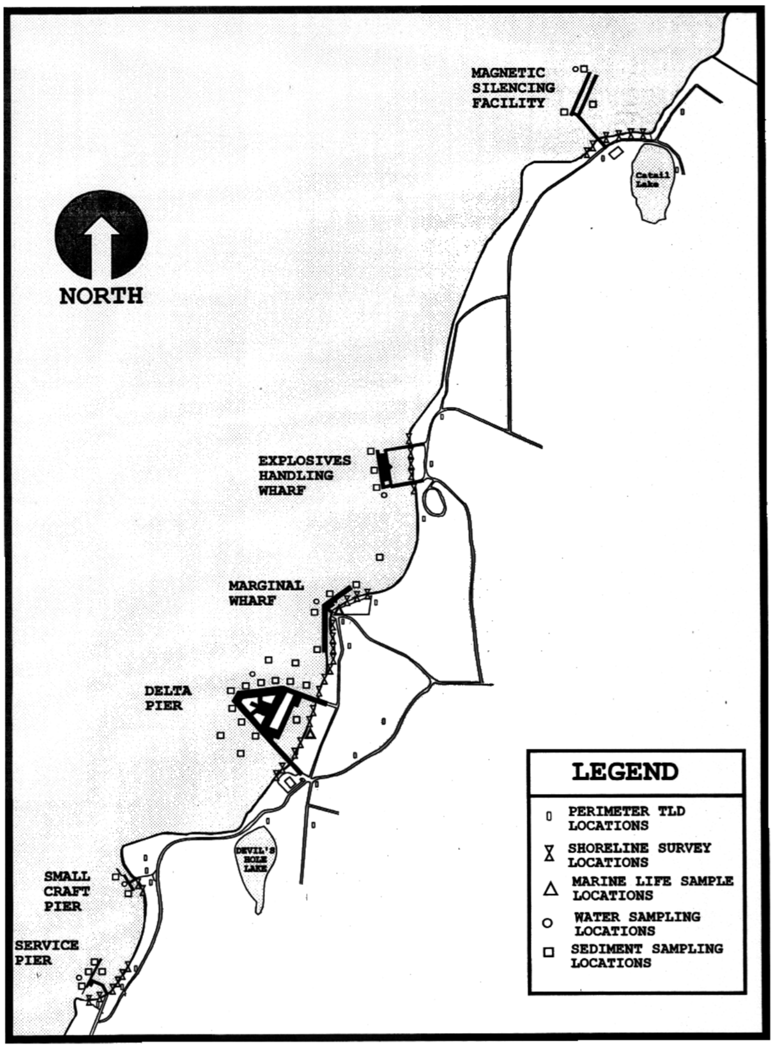
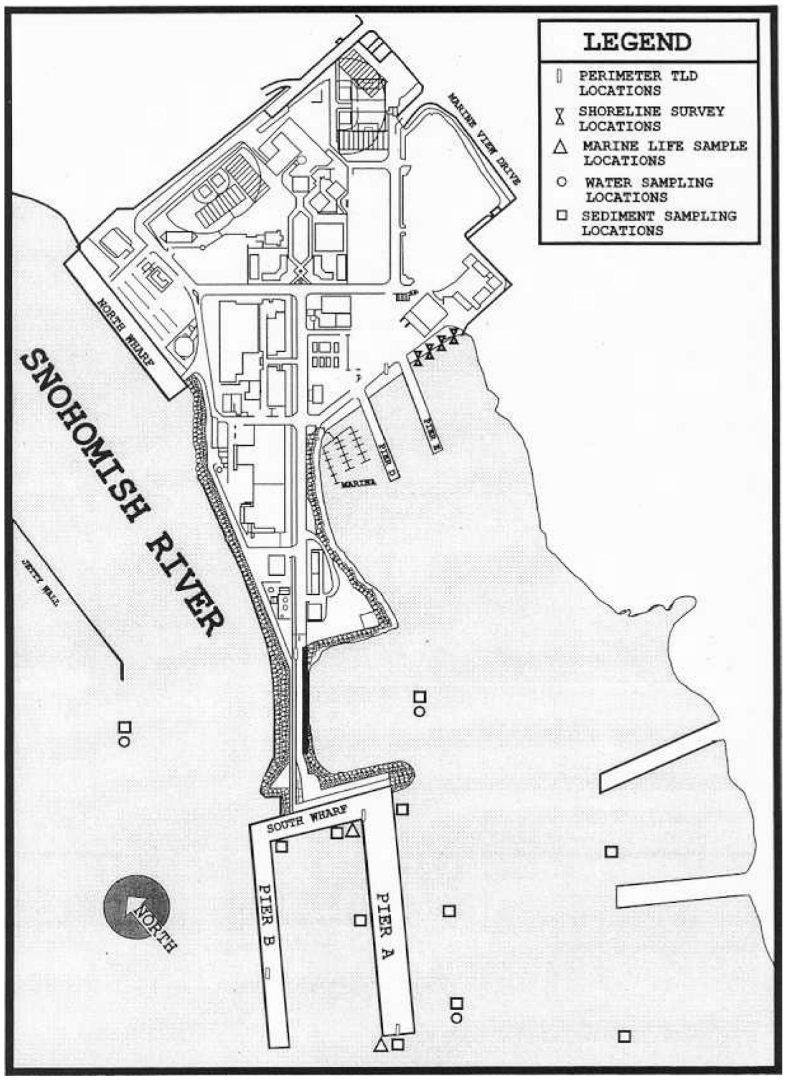


FIGURE 20
ENVIRONMENTAL MONITORING LOCATIONS AT
U. S. NAVAL STATION, EVERETT, WA



REPORT NT-03-2
MARCH 2003

OCCUPATIONAL RADIATION EXPOSURE FROM U.S. NAVAL NUCLEAR PLANTS AND THEIR SUPPORT FACILITIES

NAVAL NUCLEAR PROPULSION PROGRAM
DEPARTMENT OF THE NAVY
WASHINGTON, D.C. 20350

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March 2003

OCCUPATIONAL RADIATION EXPOSURE FROM U.S. NAVAL NUCLEAR PROPULSION PLANTS AND THEIR SUPPORT FACILITIES

2002

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

SUMMARY

Radiation exposures to Navy and civilian personnel monitored for radiation associated with U.S. naval nuclear propulsion plants are summarized in this report. As of the end of 2002, the U.S. Navy operated 73 nuclear-powered submarines, 9 nuclear-powered aircraft carriers, and 2 moored training ships. Facilities involved in construction, maintenance, overhaul, and refueling of these nuclear propulsion plants include six shipyards, two tenders, and five naval bases. The benefits of nuclear propulsion in our most capable combatant ships have long been recognized, and our nuclear-powered ballistic missile submarines form the most invulnerable element of the U.S. strategic deterrent.

Figure 1 shows that the total radiation exposure in 2002 is about 8 percent of the amount in the peak year of 1966, even though today there are over 20 percent more nuclear-powered ships in operation and more than two and a half times the number of ships in overhaul. Total radiation exposure in this figure is the sum of the annual exposures of each person monitored for radiation. An increase in shipyard workload is expected in the next decade as an increased number of ships undergo mid-life refueling overhauls. Since refueling overhaul exposure totals are routinely higher than other types of overhauls, shipyard exposure totals are expected to increase as well. For this reason, the total shipyard radiation exposure increased from 915 rem in 2001 to 1,087 rem in 2002 with a corresponding increase in total fleet radiation exposure from 723 rem in 2001 to 744 rem in 2002.

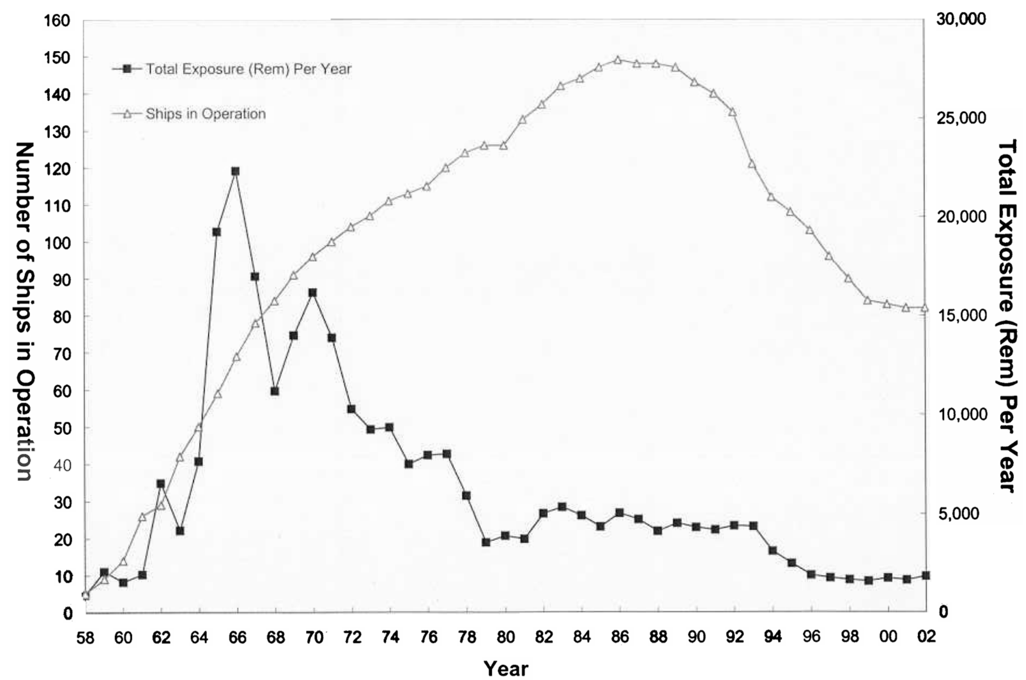
No civilian or military personnel in the Naval Nuclear Propulsion Program have ever exceeded the Federal accumulated limit, which until 1994 allowed 5 rem of exposure for each year of age beyond age 18. Since 1967, no person has exceeded the Federal limit, which allows up to 3 rem per quarter year. Since 1968, no one has exceeded the Navy's self-imposed limit of 5 rem per year for radiation associated with naval nuclear propulsion plants. The Federal limit was changed in 1994 to adopt the 5 rem per year limit already in use by the Navy, in lieu of the accumulated exposure limit.

Since 1962, no civilian or military personnel in the Naval Nuclear Propulsion Program have ever received more that one-tenth the Federal annual occupational exposure limit from internal radiation exposure caused by radioactivity associated with naval nuclear propulsion plants.

The average occupational exposure of each person monitored since 1954 for radiation associated with naval nuclear propulsion plants is less than one-sixth of a rem per year. The total lifetime average exposure during this 49-year period is about 1 rem per person.

According to the standard methods for estimating risk, the risk to the group of personnel occupationally exposed to radiation associated with naval nuclear propulsion plants is less than the risk these same personnel have from exposure to natural background radiation. This risk is small compared to the risks accepted in normal industrial activities, and it is small compared to the risks regularly accepted in daily life outside of work.

FIGURE 1
TOTAL RADIATION EXPOSURE RECEIVED BY
MILITARY AND CIVILIAN PERSONNEL IN THE NAVAL
NUCLEAR PROPULSION PROGRAM 1958 - 2002



EXTERNAL RADIATION EXPOSURE

Policy and Limits

The policy of the U.S. Naval Nuclear Propulsion Program is to reduce exposure to personnel from ionizing radiation associated with naval nuclear propulsion plants to a level as low as reasonably achievable.

Prior to 1960, the Federal radiation exposure limit used in the U.S. for whole body radiation was 15 rem per year [1]. From 1960 to 1994, the Federal radiation exposure limits used in the U.S. for whole body radiation exposure were 3 rem per quarter year and 5 rem accumulated dose for each year beyond age 18. These limits were recommended in 1958 by the U.S. National Committee ("Committee" was changed to "Council" when the organization was chartered by the U.S. Congress in 1964) on Radiation Protection and Measurements (reference 1)[2] and by the International Commission on Radiological Protection (reference 2). They were adopted by the U.S. Atomic Energy Commission (AEC) and applied both within the AEC and to licensees in 1960 (reference 3). On May 13, 1960, President Eisenhower approved the U.S. Federal Radiation Council recommendation that these limits be used as guidance for Federal agencies (reference 4). The U.S. Department of Labor adopted these same limits. A key part of each of these standards has been emphasis on minimizing radiation exposure to personnel.

In 1965, the International Commission on Radiological Protection (reference 5) reiterated the quarterly and accumulated limits cited above but suggested that exceeding 5 rem in 1 year should be infrequent. Although none of the other organizations referred to above changed their recommendations accordingly, the Naval Nuclear Propulsion Program adopted 5 rem per year as a rigorous limit, effective in 1967.

In 1971, the National Council on Radiation Protection and Measurements (reference 6) recommended that 5 rem be adopted as the annual limit under most conditions. In 1974, the AEC (now the Department of Energy) (reference 7) established 5 rem as its annual limit. In 1977, the International Commission on Radiological Protection (reference 8) deleted the accumulated limit and recommended 5 rem as the annual limit. In 1979, the Nuclear Regulatory Commission issued a proposed change to the Code of Federal Regulations, Title 10, Part 20, to require its licensees to use 5 rem as an annual limit. On January 20, 1987, revised guidance for Federal agencies was approved by President Reagan that eliminated the accumulated dose limit discussed above and established a 5 rem per year limit for occupational exposure to radiation (reference 9). The Nuclear Regulatory Commission approved the change to the Code of Federal Regulations, Title 10, Part 20, that made the 5 rem annual limit effective on or before January 1, 1994.

The Naval Nuclear Propulsion Program radiation exposure limits since 1967 have been:

3 rem per quarter
5 rem per year

Special higher limits are in effect, such as those for hands and feet; however, there have been few cases where these limits have been more restrictive than the whole body radiation exposure limits. Therefore, the radiation exposures discussed in this report are nearly all from whole body radiation. Controls are also in effect to minimize any occupational radiation exposure to the unborn child of a pregnant worker.

---

1. 1 rem = 0.01 Sievert
2. References are listed on pages 47 through 49.

Each organization in the Naval Nuclear Propulsion Program is required to have an active program to reduce radiation exposure to the minimum practicable.

Source of Radiation

The radiation discussed in this report originates from pressurized water reactors. Water circulates through a closed piping system to transfer heat from the reactor core to a secondary steam system isolated from the reactor cooling water. Trace amounts of corrosion and wear products are carried by reactor coolant from reactor plant metal surfaces. Some of these corrosion and wear products are deposited on the reactor core and become radioactive from exposure to neutrons. Reactor coolant carries some of these radioactive products through the piping systems where a portion of the radioactivity is removed by a purification system. Most of the remaining radionuclides transported from the reactor core deposit in the piping systems.

The reactor core is installed in a heavy-walled pressure vessel within a primary shield. This shield limits radiation exposure from the gammas and neutrons produced when the reactor is at power. Reactor plant piping systems are installed primarily inside a reactor compartment that is surrounded by a secondary shield. Access to the reactor compartment is permitted only after the reactor is shut down. Most radiation exposure to personnel comes from inspection, maintenance, and repair inside the reactor compartment. The major source of this radiation is cobalt-60 deposited inside the piping systems. Cobalt-60 emits two high-energy gammas and a low-energy beta for every radioactive decay. Its half-life is 5.3 years.

Neutrons that are produced when reactor fuel fissions are shielded by primary and secondary shields. Radiation exposure to personnel from these neutrons during reactor operation is much less than from gammas. After reactor shutdown, when shipyard and other support facility work is done, no neutron exposure is detectable. As a result, the radiation exposures discussed in this report are nearly all from gamma radiation.

Control of Radiation During Reactor Plant Operation

Reactor plant shielding is designed to minimize radiation exposure to personnel. Shield design criteria establishing radiation levels in various parts of each nuclear-powered ship are personally approved by the Director, Naval Nuclear Propulsion.

Ship design is also controlled to keep locations such as duty stations, where personnel need to spend time, as far as practicable away from the reactor compartment shield. Special attention is paid to living quarters. For example, the shield design criteria were established such that a person would have to spend more than 48 hours per day in living quarters to exceed exposure limits (which is impossible, there being only 24 hours in a day).

Radiation resulting outside the propulsion plant spaces during reactor plant operation is generally not any greater than natural background radiation. For submarine personnel stationed outside the propulsion plant, the combination of low natural radioactivity in ship construction materials and reduced cosmic radiation under water results in less radiation exposure (from all sources including the nuclear reactor) at sea than the public receives from natural background sources ashore. Those who operate the nuclear propulsion plant receive more radiation exposure in port during maintenance and overhaul periods than they receive from operating the propulsion plant at sea.

Control of Radiation in Support Facilities

Special support ships called tenders for nuclear-powered ships are constructed so that radioactive material is handled only in specially designed and shielded nuclear support facilities. Naval bases and shipyards limit to the minimum the number of places where radioactive material is allowed. Stringent controls are in place during the movement of all radioactive material outside these nuclear support facilities. A radioactive material accountability system is used to ensure no radioactive material is lost or misplaced in a location where personnel could unknowingly be exposed. Regular inventories are required for every item in the radioactive material accountability system. Radioactive material is tagged with yellow and magenta tags bearing the standard radiation symbol and the measured radiation level. Radioactive material removed from a reactor plant is required to be placed in yellow plastic, and the use of yellow plastic is reserved solely for radioactive material. All personnel assigned to a tender, naval base, or shipyard are trained to recognize that yellow plastic identifies radioactive material and to initiate immediate action if radioactive material is discovered out of place.

Access to radiation areas is controlled by signs and barriers. Personnel are trained in the access requirements, including the requirement to wear dosimetry devices to enter these areas. Dosimetry devices are also posted near the boundaries of these areas to verify that personnel outside these areas do not require monitoring. Frequent radiation surveys are required using instruments that are checked before use and calibrated regularly. Areas where radiation levels are greater than 0.1 rem per hour are called “high radiation areas” and are locked or guarded. Compliance with radiological controls requirements is checked frequently by radiological controls personnel, as well as by other personnel not affiliated with the radiological controls organization.

Dosimetry

Thermoluminescent dosimeters (TLDs) have been the dosimetry devices worn by personnel to measure their exposure to gamma radiation since 1974. Prior to 1974, film badges were used as described below. The TLD contains two chips of calcium fluoride with added manganese. It is characteristic of thermoluminescent material that radiation causes internal changes which make the material, when subsequently heated, give off an amount of light directly proportional to the radiation dose. In order to make it convenient to handle, these chips of calcium fluoride are in contact with a metallic heating strip with heater wires extending through the ends of a surrounding glass envelope. The glass bulb is protected by a plastic case designed to permit the proper response to gammas of various energies. Gammas of such low energy that they will not penetrate the plastic case constitute less than a few percent of the total gamma radiation present. To read the radiation exposure, a trained operator removes the glass bulb and places it in a TLD reader, bringing the metal heater wires into contact with an electrical circuit. An electronically controlled device heats the calcium fluoride chips to several hundred degrees Celsius in a timed cycle, and the intensity of light emitted is measured and converted to a digital readout in units of rem. The heating cycle also anneals the calcium fluoride chips so that the dosimeter is zeroed and ready for subsequent use. The entire cycle of reading a TLD described here takes about 30 seconds. This rapid readout capability was one reason for changing from film badges to TLDs. The use of TLDs permits more frequent measurement of a worker's radiation exposure than film badges did. TLDs are required to be processed at least weekly in naval shipyards, and at least monthly aboard ship. However, daily processing is required for anyone entering a reactor compartment or high radiation area.

To ensure accuracy of the TLD system, periodic calibration and accuracy checks are performed. For example, TLDs are checked when new, and once every 6 months thereafter, for accurate response to a known radiation exposure. Those that fail are discarded. TLD readers are calibrated once each year by one of several calibration

facilities using precision radiation sources and precision TLD standards. In addition, weekly, daily, and hourly checks of proper TLD reader operation and accuracy are performed when readers are in use, using internal electronic standards built into each reader.

In addition to these calibrations and checks, the Navy has an independent dosimetry quality assurance program to monitor the accuracy of TLDs and TLD readers in use at Program activities. Precision TLDs are pre-exposed to exact amounts of radiation by the National Institute of Standards and Technology (formerly the National Bureau of Standards) and provided to Program activities for reading. The activity's results are then compared to the actual exposures. A random sample of dosimeters in use at the activity being tested is also selected and sent to a Navy shore facility for accuracy testing. To ensure objectivity, the activity being tested is not told of the radiation values to which the dosimeters have been exposed and is not permitted to participate in the selection of the dosimeter sample. If these tests find any inaccuracies that exceed established permissible error, appropriate corrective action (such as recalibration of a failed TLD reader) is immediately taken. The results of this program demonstrate that the radiation to which personnel are exposed is being measured by the TLD system with an average error of less than 10 percent.

The Naval Nuclear Propulsion Program dosimetry system is accredited under the National Voluntary Laboratory Accreditation Program. This voluntary program, sponsored by the National Institute of Standards and Technology, provides independent review of dosimetry services for consistency with accepted standards.

Pocket ionization chambers with an eyepiece permit wearers to read and keep track of their own radiation exposure during a work period. This pocket dosimeter is required in addition to a TLD when entering a reactor compartment or a high radiation area. The official record of radiation exposure is obtained from the TLD.

Dosimetry devices are worn on the trunk of the body, normally at the waist or chest. In some special situations additional dosimeters are worn at other locations, for example on the hands, fingers or head.

Discrepancies between TLD and pocket dosimeter measurements are investigated. These investigations include making independent, best estimates of the worker's exposure using such methods as time spent in the specific radiation area and comparing the estimates with the TLD and pocket dosimeter measurements to determine which measurement is the more accurate.

In 1974, the conversion from film badges to TLDs for measuring radiation exposure was completed. Before 1974, film packets like those used for dental x-rays were placed in holders designed to allow differentiating between types of radiation. The darkness of the processed film was measured with a densitometer and converted to units of radiation exposure. When the first personnel radiation exposures were measured in the Naval Nuclear Propulsion Program, there already was widespread photodosimetry experience in the Navy and precise procedures existed to provide reproducible results.

Each film badge was clearly marked with a name or number corresponding to the individual to whom it was assigned. This number was checked by a radiological controls technician before a worker entered a high radiation area. In high radiation areas every worker also wore a pocket dosimeter, which was read by radiological controls personnel when the worker left the area. At the end of each month when the film badges were processed, the film badge measurements were compared with the sum of the pocket dosimeter readings. The film badge results were, with few exceptions, entered in the permanent personnel radiation exposure records. The few exceptions where film badge results were not entered into exposure records occurred

when material problems with the film caused abnormal readings, such as film clouding. In such cases, a conservative estimate of exposure was entered.

Results of numerous tests conducted by shipyards under the same conditions that most radiation exposure was received showed that film measurements averaged 15 percent higher than actual radiation exposures. This was a conscious conservatism to ensure that even in the worst case, the film measurement was not less than the actual radiation exposure. Film response varies with the energy of the gamma radiation. The calibration of the film was performed at high energy where the film has the least response to radiation exposure. Radiation of lower energies corresponding to scattered radiation from shielded cobalt-60 caused the film to indicate more radiation exposure than is present.

Data gathered in over 20 years of neutron monitoring aboard ships using neutron film badges demonstrated that the monitored individuals did not receive neutron exposure above the minimum detection level for neutron film. Naval nuclear-powered ships and their support facilities now use lithium fluoride TLDs to monitor neutron exposure of the few personnel exposed to neutron sources, such as for radiation instrument calibration and for reactor plant instrumentation source handling. These measured neutron exposures have been added to gamma exposures in the total whole body radiation exposure in this report, but because neutron exposures are so low, the radiation exposures in this report are almost entirely from gamma radiation.

Monitoring for beta radiation is not normally required, because betas cannot penetrate the metal boundaries of the reactor coolant system. Beta radiation needs to be considered in maintenance or repair operations only when systems are opened and personnel are close to surfaces that have been contaminated with radioactive corrosion products from reactor coolant. In these cases anticontamination clothing, faceshields, or plastic contamination control materials effectively shield the individual from beta radiation of the energies normally present. Support facilities routinely provide such materials to eliminate personnel radiation exposure from betas.

Monitoring for alpha radiation is not a normal part of operation or maintenance of naval nuclear propulsion plants. However, alpha monitoring is sometimes necessary to identify radon daughter products naturally present in the atmosphere.

Physical Examinations

Radiation medical examinations have been required since the beginning of the Naval Nuclear Propulsion Program for personnel who handle radioactive material or have the potential to exceed in 1 year the exposure allowed to a member of the general public (i.e., 0.1 rem). These examinations are conducted in accordance with the Navy's Radiation Health Protection Manual (reference 10). In these examinations the doctor pays special attention to any condition that might medically disqualify a person from receiving occupational radiation exposure or pose a health or safety hazard to the individual, to co-workers, or to the safety of the workplace.

Passing this examination is a prerequisite for obtaining dosimetry, which permits entry to high radiation and radiologically controlled areas and allows handling of radioactive material. Few of the military personnel who have already been screened by physical examinations fail this radiation medical examination. For civilian shipyard workers, the failure rate is a few percent. However, failure of this examination does not mean a shipyard worker will not have a job. Since shipyard workers spend most of their time on non-radioactive work, inability to qualify for radioactive work does not restrict their job opportunities. No shipyard worker in the Naval Nuclear Propulsion Program has been fired for inability to pass a radiation medical examination.

When required, radiation medical examinations are given prior to initial work, periodically thereafter depending on the worker's age, and at termination of radioactive work in the Naval Nuclear Propulsion Program (or at termination of employment). The periodic examinations are conducted in accordance with the following frequencies:

Age	Interval
18-24	Pre-placement
25-49	5 years
50-59	2 years
>60	1 year

A radiation medical examination includes review of medical history to determine, among other subjects, past radiation exposure, history of cancer, history of radiation therapy, and family history of cancer. In the medical examination, particular attention is paid to evidence of cancer or a precancerous condition. Laboratory procedures include urinalysis, blood analysis, and comparison of blood constituents to a specific set of standards. If an examination of naval civilian or military personnel disqualifies the individual, the individual is restricted from receiving occupational radiation exposure and the results of the examination are reviewed by the Bureau of Medicine and Surgery's Radiation Effects Advisory Board. Only after approval of the Board would the individual be permitted to receive occupational radiation exposure.

Shipyard, Tender, and Naval Base Training

Periodic radiological controls training is performed to ensure that all workers understand the general and specific radiological aspects which they might encounter, understand their responsibility to the Navy and the public for safe handling of radioactive materials, understand the risks associated with radiation exposure, and understand their responsibility to minimize their own radiation exposure. Training is also provided on the biological risk of radiation exposure to the unborn child. Before being authorized to perform radioactive work, an employee is required to pass a radiological controls training course, including a written examination. Typical course lengths for workers range from 16 to 32 hours. In written examinations on radiological controls, short-answer questions (such as multiple choice or true-false) are prohibited. The following are the training requirements for a fully qualified worker:

1. Radiation Exposure Control:

   a. State the limits for whole body penetrating radiation. Explain that the rem is a unit of biological dose from radiation.

   b. Discuss the importance of the individual keeping track of his/her own exposure. Know how to obtain year-to-date exposure information.

   c. Know that local administrative control levels are established to maintain personnel radiation exposure as low as reasonably achievable. Know his/her own exposure control level and who can approve changes to this level.

   d. Discuss procedures and methods for minimizing exposure, such as working at a distance from a source, reducing time in radiation areas, and using shielding.

   e. Know that a worker is not authorized to move, modify, or add temporary shielding without specific authorization.

   f. Discuss potential sources of radiation associated with work performed by the individual's trade.

g. Discuss the action to be taken if an individual loses dosimetry equipment while in a posted radiation or high radiation area.

h. Discuss how to obtain and turn in dosimetry equipment.

i. Know that thermoluminescent dosimetry equipment is required to be worn on the portion of the individual's body that receives the highest exposure and that pocket dosimeters are worn at the same location on the body as the thermoluminescent dosimetry. Know that only radiological controls personnel can authorize movement of dosimetry equipment from areas of the body where dosimetry is normally worn (such as the chest or waist) to other areas of the body.

j. Be aware of the seriousness of violating instructions on radiation warning signs and unauthorized passage through barriers.

k. Explain how "stay times" are used.

l. Know that naval nuclear work at a facility has no significant effect on the environment or on personnel living adjacent to or within the facility.

m. Explain the risk associated with personnel radiation exposure. Know that any amount of radiation exposure, no matter how small, might involve some risk; however, exposure within accepted limits represents a risk that is small compared with normal hazards of life. The National Council on Radiation Protection and Measurements has stated that while exposures of workers and the general population should be kept to the lowest practicable levels at all times, the presently permitted exposures limit the risk to a reasonable level in comparison to nonradiation risks. Know that cancer is the main potential health effect of receiving radiation exposure. Know that any amount of radiation exposure to the unborn child, no matter how small the exposure, might involve some risk; however, exposure of the unborn child within accepted limits represents a risk that is small when compared with other risks to the unborn child. Know that the risk to future generations (genetic effect) is considered to be even smaller than the cancer risk and that genetic effects have not been observed in human beings.

n. Know how often an individual shall read his/her pocket dosimeter while in a posted high radiation area. Know that a worker shall leave a posted high radiation area when his/her pocket dosimeter reaches three quarters scale or when a preassigned exposure is reached, whichever is lower.

o. Know that stay times and predetermined pocket dosimeter readings are assigned when working in radiation fields of 1 rem/hour or greater. Know that the worker shall leave the work area when either the assigned stay time or pocket dosimeter reading is reached.

2. <u>Contamination Control</u>:

a. Discuss how contamination is controlled during radioactive work (e.g., containment in plastic bags and use of contamination containment areas). Explain that these controls limit exposure to internal radioactivity to insignificant levels.

b. Discuss how contamination is detected on personnel.

c. Discuss how contamination is removed from objects and personnel.

d. Discuss potential sources of contamination associated with work performed by the individual's trade.

e. State the beta-gamma surface contamination limit. Discuss the meaning of the units of the limit.

f. Explain what radioactive contamination is. Explain the difference between radiation and radioactive contamination.

g. For personnel who are trained to wear respiratory protection equipment, state the controls for use of such equipment. Know that the use of a respirator is based on minimizing inhalation of radioactivity. Know that the respirators used for radiological work are not used for protection in any atmospheres that threaten life or health. Therefore, know that the proper response to a condition in which supply air is lost or breathing becomes difficult is to remove the respirator.

h. Discuss the required checks to determine whether personnel contamination monitoring equipment is operational prior to conducting personnel monitoring. Discuss the action to be taken if the checks indicate the equipment is not operating properly.

i. Discuss the actions to be taken if personnel contamination monitoring equipment alarms while conducting personnel monitoring.

j. Discuss the procedure to package and remove a contaminated item from a controlled surface contamination area.

k. Know that no health effects are expected from receiving radioactive contamination, on the skin, associated with naval nuclear propulsion plants.

l. Discuss the procedures for donning and removing a full set of anticontamination clothing.

3. <u>Accountability of Radioactive Materials</u>: Know that radioactive materials are accounted for when transferred between radiologically controlled areas by tagging, tracking location, and using radioactive material escorts.

4. <u>Waste Disposal</u>:

a. Discuss how individual workers can reduce the amount of radioactive liquid and solid waste generated for the specific type of duties performed.

b. Discuss the importance of properly segregating non-contaminated, potentially contaminated, and contaminated material.

c. Know what reactor plant reuse water is. Discuss the appropriate uses of reactor plant reuse water.

5. <u>Radiological Casualties</u>:

a. Discuss the need for consulting radiological controls personnel when questions or problems occur. Understand the importance of complying with the instructions of radiological controls personnel in the event of a problem involving radioactivity.

b. Discuss procedures to be followed in the event of a spill of material (liquid or solid) which is or might be radioactive.

c. Discuss procedures to be followed when notified that airborne radioactivity is above the limit.

d. Discuss procedures to be followed in the event that a high radiation area is improperly controlled.

e. Discuss actions to be taken when an individual discovers his/her pocket dosimeter is off-scale or has recorded a higher reading than expected.

6. Responsibilities of Individuals: Discuss actions required in order to fulfill the worker's responsibilities. Discuss the responsibility of the individual to notify the Radiation Health Department or the Medical Department of radiation medical therapy, medical diagnosis involving radioisotopes, open wounds or lesions, physical conditions which the worker feels affect his or her qualification to receive occupational radiation exposure, or occupational radiation exposure from past or current outside employment. Discuss the responsibility of the individual to report to area supervision or radiological controls personnel any condition that might lead to or cause avoidable exposure to radiation.

7. Practical Ability Demonstrations: These demonstrations are performed on a mockup.

a. Demonstrate the ability to read all types of pocket dosimeters used by the organization.

b. For applicable workers, demonstrate the proper procedure for donning and removing a full set of anticontamination clothing.

c. Demonstrate the proper procedures for entering and leaving a high radiation area, a radiologically controlled area, and a control point area, including proper procedures for self-monitoring. Demonstrate the ability to read and interpret posted radiation and contamination survey maps.

d. For applicable workers, demonstrate the ability to properly package and remove an item from a controlled surface contamination area.

e. Demonstrate action to be taken by one or two workers in the event of a spill of radioactive liquid.

f. For personnel who will enter or remain in areas where respiratory protection equipment is required, demonstrate the proper procedure for inspection and use of the type(s) of respiratory equipment the individual will be required to wear as part of mockup training for the job. This includes demonstrating donning and removing the type of respiratory equipment in conjunction with anticontamination clothing, if anticontamination clothing is required to be worn with the respiratory equipment. In addition, individuals who are trained to wear air-fed hoods demonstrate the proper response if supply air is lost while wearing an air-fed hood.

g. For personnel who are trained to work in contamination containment areas, demonstrate the proper procedures for working in these areas. This demonstration includes a pre-work inspection, transfer of an item into the area, a work evolution in the area, and transfer of an item out of the area.

In addition to passing a written examination, completion of this training course requires satisfactory performance during basic types of simulated work operations. To continue as a radiation worker, personnel must requalify in a manner similar to the initial qualification at least every 2 years. Between these qualification periods, personnel are required to participate in a continuing training program, and the effectiveness of that continuing training is validated through random knowledge retention testing. Training is also conducted by individual shop instructors in the specific job skills for radiation work within each trade. For complex jobs this is followed by special training for the specific job, frequently using mockups outside radiation areas.

Radiological controls technicians are required to complete a 6-12 month course in radiological controls, to demonstrate their practical abilities in work operations and drills, and to pass comprehensive written and oral examinations. Radiological controls supervisors are required to have at least the same technical knowledge and abilities as the technicians; however, passing scores for supervisors' examinations are either higher or more difficult to attain than they are for technicians. Oral examinations, which are conducted by radiological controls managers and senior supervisors, require personnel to be able to evaluate symptoms of unusual radiological controls situations. The radiological controls technician or supervisor is required to evaluate initial symptoms, state immediate corrective action required, state what additional measurements are required, and do a final analysis of the measurements to identify the specific problem. Subsequent to qualification, periodic training sessions are required in which each radiological controls technician and supervisor demonstrates the ability to handle situations similar to those covered in the oral examinations. At least every 2½ years, radiological controls personnel have to requalify through written and practical abilities examinations similar to those used for initial qualification. Additionally, their first requalification includes an oral examination similar to the one required for initial qualification. Between qualification periods, radiological controls technicians and supervisors are required to be selected at random for additional written and practical abilities examinations. They also must participate in unannounced drills.

In addition to the above training for those who are involved in radioactive work, each shipyard employee not involved in radioactive work and each person assigned to a nuclear-powered ship or a support facility is required to receive basic radiological training which is repeated at least annually. This training is to ensure personnel understand the posting of radiological areas, the identification of radioactive materials, and not to cross radiological barriers. This instruction also explains that the radiation environment of personnel outside radiation areas and outside the ship or shipyard is not significantly affected by nuclear propulsion plant work.

<u>Nuclear Power Training</u>

Military personnel who operate naval nuclear propulsion plants are required to pass a 6-month basic training course at Nuclear Power School and a 6-month qualification course at a land-based prototype of a shipboard reactor plant or moored training ship. Each nuclear-trained officer and enlisted person receives extensive radiological controls training, including lectures, demonstrations, practical work, radiological controls drills, and written and oral examinations. This training has emphasized the ability to apply basic information on radiation and radioactivity.

Those enlisted personnel who will have additional responsibilities for radiological controls associated with operation of nuclear propulsion plants are designated Engineering Laboratory Technicians and receive an additional 3 months of training after completion of the 1-year program. Engineering Laboratory Technicians and other selected nuclear trained personnel who are assigned radiological controls duties at naval bases and tenders normally receive an additional intensive 4-month training

program in the practical aspects of radiological controls associated with maintenance and repair work.

Before becoming qualified to head the engineering department of a nuclear-powered ship, a nuclear-trained officer must pass a written examination and a sequence of oral examinations conducted at Naval Nuclear Propulsion Program Headquarters. A key part of these qualification examinations is radiological controls.

Any officer who is to serve as commanding officer of a nuclear-powered ship must attend a 3-month course at the Naval Nuclear Propulsion Program Headquarters. The radiological controls portion of this course covers advanced topics and assumes the officer starts with detailed familiarity with shipboard radiological controls. The officer must pass both written and oral examinations in radiological controls during this course before assuming command of a nuclear-powered ship.

Radiation Exposure Reduction

Keeping personnel radiation exposures as low as reasonably achievable involves all levels of management in nuclear-powered ships and their support facilities. Operations, maintenance, and repair personnel are required to be involved in this subject; it is not left solely to radiological controls personnel. To evaluate the effectiveness of radiation exposure reduction programs, managers use a set of goals. Goals are set in advance to keep each worker's exposure under certain levels and to minimize the number of workers involved. Goals are also set on the total cumulative personnel radiation exposure for each major job, for the entire overhaul or maintenance period, and for the whole year. These goals are deliberately made hard to meet in order to encourage personnel to improve performance.

Of the various goals used, the most effective in reducing personnel radiation exposure has been the use of individual exposure control levels, which are lower than the Navy's quarterly and annual limits. Control levels in shipyards range from 0.5 rem to 2 rem for the year (depending on the amount of radioactive work scheduled), whereas 5 rem per year is the Navy limit.

To achieve the benefits of lower control levels in reducing total radiation exposure, it is essential to minimize the number of workers permitted to receive radiation exposure. Otherwise the control levels could be met merely by adding more workers. Organizations are required to conduct periodic reviews to ensure the number of workers is the minimum for the work that has to be performed.

The following is a synopsis of the checklist that has been in use for years to keep personnel radiation exposure as low as reasonably achievable during maintenance, overhaul, and repair.

Preliminary Planning

- Plan well in advance
- Delete unnecessary work
- Determine expected radiation levels

Preparation of Work Procedures

- Plan access to and exit from work area
- Provide for service lines (air, welding, ventilation, etc.)
- Provide communication (sometimes includes closed-circuit television)
- Remove sources of radiation
- Plan for installation of temporary shielding

- Decontaminate
- Work in lowest radiation levels
- Perform as much work as practicable outside radiation areas
- State requirements for standard tools
- Consider special tools
- Include inspection requirements (these identify steps where r controls personnel must sign before the work can proceed)
- Minimize discomfort of workers
- Estimate total radiation exposure

Temporary Shielding

- Control installation and removal by written procedure
- Inspect after installation
- Conduct periodic radiation surveys
- Minimize damage caused by heavy lead temporary shielding
- Balance radiation exposure received in installation against e: saved by installation
- Shield travel routes
- Shield components with abnormally high radiation levels early maintenance period
- Shield the work area based on worker body position
- Perform directional surveys to improve design of shielding by sources of radiation
- Use mockup to plan temporary shielding design and installati

Rehearsing and Briefing

- Rehearse
- Use mockup duplicating working conditions
- Use photographs
- Brief workers

Performing Work

- Post radiation levels
- Keep excess personnel out of radiation areas
- Minimize beta radiation exposure (anticontamination clothing shields cobalt-60 betas)
- Supervisors and workers keep track of radiation exposure
- Workers assist in radiation and radioactivity measurements
- Evaluate use of fewer workers
- Reevaluate reducing radiation exposures

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Since its inception, the Naval Nuclear Propulsion Program has stressec personnel radiation exposure. Beginning in the 1960s, a key part of the effort in this area has involved minimizing radioactive corrosion products reactor plant, which in turn has significantly contributed to reducing pers exposure. Additional measures that have been taken to reduce exposu standardization and optimization of procedures, development of new to use of temporary shielding, and compliance with strict contamination co For example, most work involving radioactive contamination is performe containment. This practice minimizes the potential for spreading contar thus reduces work disruptions, simplifies working conditions, and minim and the exposure during clean up.

Lessons learned during radioactive work and new ways to reduce exposure developed at one organization are made available for use by other organizations in the Naval Nuclear Propulsion Program. This effort allows all of the organizations to take advantage of the experience and developments at one organization and minimizes unnecessary duplication of effort.

The extensive efforts that have been taken to reduce exposure in the Naval Nuclear Propulsion Program have also had other benefits, such as reduced cost to perform radioactive work and improved reliability. Among other things, detailed work planning, rehearsing, total containment, special tools, and standardization have increased efficiency and improved access to perform maintenance, with the overall result that reliability is improved and costs are reduced.

Radiation Exposure Data

Radioactive materials had been handled in shipyards for years before naval nuclear propulsion plant work started. Examples of such work include non-destructive testing using radiography sources and radiation instrument calibration using radioactive sources. Since this work is licensed by the Nuclear Regulatory Commission or by a State under agreement with the Nuclear Regulatory Commission, the radiation exposure from this licensed work has been excluded whenever practicable from this report of occupational exposure received from naval nuclear propulsion plants and their support facilities.

Table 1 shows the dates when radioactive work associated with naval nuclear propulsion plants started in each of the 11 shipyards. Seven of these shipyards have constructed naval nuclear-powered ships; however, little radiation exposure is received in new construction. The dates of starting reactor plant overhaul, therefore, are the significant dates for start of radioactive work.

The total occupational radiation exposure received by all personnel in the Naval Nuclear Propulsion Program in 2002 was 1,831 rem. Table 2 summarizes radiation exposure received in nuclear-powered ships and their supporting tenders and naval bases since the first nuclear-powered ship went to sea in January 1955. Most of the radiation exposure in this table results from inspection, maintenance, and repair work in the reactor compartments of ships. In general, radiation exposures for reactor compartment work increase as reactor plant radiation levels increase with the age of the plant.

Table 3 summarizes radiation exposures of shipyard personnel since the start of naval nuclear propulsion plant radioactive work in 1954. Figure 2 shows the total personnel radiation exposure alongside the amount of work at the shipyards. Since ship overhauls frequently overlapped calendar years, the numbers of ships in overhaul shown in Figure 2 were determined by dividing by 12 the total number of months each ship was in overhaul during a calendar year. Overhauls include defueling and inactivation of decommissioned ships.

Figure 2 shows that, from the peak in 1966 until the 1990s, total personnel radiation exposure was reduced in the shipyards while the amount of work had increased. An increase in shipyard workload is expected in the next decade as an increased number of ships undergo mid-life refueling overhauls. Since refueling overhaul exposure totals are routinely higher than other types of overhauls, shipyard exposure totals are expected to increase as well. For this reason, the total shipyard radiation exposure increased from 915 rem in 2001 to 1,087 rem in 2002 with a corresponding increase in total fleet radiation exposure from 723 rem in 2001 to 744 rem in 2002.

The increase in the numbers of personnel monitored and total radiation exposure in the early years shows the increasing workload in reactor plant work as the number of ships increased. By 1962, four submarine reactor plants had been overhauled and major efforts were underway to reduce radiation levels. By 1966, the number of ships in overhaul had quadrupled, as indicated by the buildup to the peak in total radiation exposure. Subsequently, the number of ships in overhaul more than quadrupled again. Decreases in total annual exposures, numbers of personnel monitored, and numbers of personnel with annual exposures over 2 rem have been as a result of efforts to reduce radiation exposures to the minimum practicable. Since 1954, the total annual exposure for the shipyards has averaged less than 4,200 rem, and less than 1,600 rem for ships.

Since a worker usually is exposed to radiation in more than one year, the total number of personnel monitored cannot be obtained by adding the annual numbers. The total number of shipyard personnel monitored for radiation exposure associated with the Naval Nuclear Propulsion Program is about 163,000. Nearly all of these are civilians, over half of whom are U.S. Government employees at four current and two former naval shipyards. Table 4 provides further information about the distribution of their radiation exposures. In 2002, more than 97 percent of those monitored for radiation in shipyards and more than 99 percent of those in ships received less than 0.5 rem in a year. Since 1954, the average exposure per year for each person monitored has been 0.226 rem in shipyards and 0.075 rem in ships, which are less than the 0.3 rem average annual exposure a person receives from natural background radiation (including the inhalation of radon and its progeny) (reference 11).

Table 4 also lists the numbers of personnel who have exceeded the 3 rem quarterly exposure limit. In no case did personnel exceed the pre-1994 Federal accumulated limit of 5 rem for each year of age over 18. The total number of persons who have exceeded the quarterly limit since the limit was imposed in 1960 is 37, of whom 4 were military personnel aboard ships. Of the 37 personnel, 30 had quarterly exposures in the range of 3 to 4 rem, and the highest exposure was 9.7 rem in a quarter. Navy procedures require any person who receives greater than 25 rem in a short time period to be placed under medical observation. No one has ever reached this level. Furthermore, since 1967 no person has exceeded the Federal limit, which allows up to 3 rem per quarter year. Additionally, since 1968 no person has exceeded the Navy's self-imposed limit of 5 rem per year for radiation associated with naval nuclear propulsion plants. The 5 rem per year limit was formally adopted as the Federal limit in 1994.

The average lifetime accumulated exposure from radiation associated with naval nuclear plants for all shipyard personnel is approximately 1.3 rem. Since the average annual exposure per person is 0.226 rem, this means that the average shipyard radiation worker is monitored because of naval nuclear propulsion plant work for approximately 6 years. The average lifetime accumulated exposure for the approximately 106,000 naval officers and enlisted personnel trained to date to operate a nuclear propulsion plant is approximately 0.73 rem. These radiation exposures are much less than the exposure the average American receives from natural background radiation or from medical diagnostic x-rays during a working lifetime (reference 11).

TABLE 1

SHIPYARD FIRST REACTOR PLANT OPERATION
AND FIRST RADIOACTIVE OVERHAUL WORK

Shipyard	Year First New Construction Reactor Started Operation	Year First Reactor Plant Overhaul Started
Electric Boat Division[3] Groton, Connecticut	1954	1957
Portsmouth Naval Shipyard Portsmouth, New Hampshire	1958	1959
Mare Island Naval Shipyard[4,5] Vallejo, California	1958	1962
Pearl Harbor Naval Shipyard Pearl Harbor, Hawaii	None	1962
Charleston Naval Shipyard [4,5] Charleston, South Carolina	None	1963
Newport News Shipbuilding Newport News, Virginia	1960	1964
Bethlehem Steel Shipbuilding[5] (Subsequently Electric Boat Division) Quincy, Massachusetts	1961	None
New York Shipbuilding Corporation[5] Camden, New Jersey	1963	None
Norfolk Naval Shipyard Portsmouth, Virginia	None	1965
Puget Sound Naval Shipyard[4] Bremerton, Washington	None	1967
Ingalls Shipbuilding Division[5] Pascagoula, Mississippi	1961	1970

3. Electric Boat Division performed overhauls from 1957 until 1977. Between 1978 and 2001, Electric Boat Division performed new construction work primarily. In 2001, Electric Boat Division began performing routine radioactive work on nuclear-powered ships.
4. Radioactive work of less extent than an overhaul began in Mare Island in 1958, in Charleston in 1961, and in Puget Sound in 1965.
5. Work on naval nuclear-powered ships was discontinued at Camden, New Jersey, in 1967; at Quincy, Massachusetts, in 1969; at Pascagoula, Mississippi, in 1980; at Vallejo, California, in 1996; and at Charleston, South Carolina, in 1996.

TABLE 2

OCCUPATIONAL RADIATION EXPOSURE RECEIVED BY PERSONNEL
ASSIGNED TO TENDERS, BASES, AND NUCLEAR-POWERED SHIPS FROM
OPERATION AND MAINTENANCE OF NAVAL NUCLEAR PROPULSION PLANTS

	Number of Persons Monitored Who Received Exposures in the Following Ranges of Rem for the Year						Total Personnel	Total Monitored
	Exposure (Rem)							
Year	**0-1**	**1-2**	**2-3**	**3-4**	**4-5**	**>5***		
1954	36	0	0	0	0	0	36	8
1955	90	11	0	0	0	0	101	25
1956	108	10	4	0	0	0	122	50
1957	293	7	1	0	0	0	301	60
1958	562	11	3	0	0	0	576	100
1959	1,057	41	8	3	0	0	1,109	200
1960	2,607	88	8	4	3	1	2,711	375
1961	4,812	106	31	4	4	0	4,957	680
1962	6,788	182	75	31	17	2	7,095	1,312
1963	9,188	197	39	14	3	1	9,442	1,420
1964	10,317	331	93	35	15	14	10,805	1,964
1965	11,883	592	224	96	30	27	12,852	3,421
1966	18,118	541	156	95	44	28	18,982	3,529
1967	21,028	339	139	48	11	0	21,565	3,084
1968	24,200	373	102	20	2	1	24,698	2,466
1969	26,969	577	127	39	6	0	27,718	2,918
1970	26,206	610	134	30	0	0	26,980	3,089
1971	26,090	568	122	31	2	0	26,813	3,261
1972	33,312	602	180	13	1	0	34,108	3,271
1973	30,852	600	102	15	1	0	31,570	3,160
1974	18,375	307	65	2	0	0	18,749	2,142
1975	17,638	330	28	1	0	0	17,997	2,217
1976	17,795	369	56	9	0	0	18,229	2,642
1977	20,236	346	95	36	3	0	20,716	2,812
1978	22,089	290	23	1	0	0	22,403	2,234
1979	21,121	75	1	0	0	0	21,197	1,528
1980	21,767	78	0	0	0	0	21,845	1,494
1981	23,781	27	0	0	0	0	23,808	1,415
1982	27,563	59	0	0	0	0	27,622	1,660
1983	27,593	52	0	0	0	0	27,645	1,832
1984	30,096	10	0	0	0	0	30,106	1,729
1985	31,447	18	0	0	0	0	31,465	1,549
1986	33,944	16	0	0	0	0	33,960	1,593
1987	34,987	2	0	0	0	0	[illegible]	1,536
1988	34,782	4	0	0	0	0	34,786	1,422
1989	35,116	52	0	0	0	0	35,168	1,599
1990	36,036	15	0	0	0	0	36,051	1,501
1991	35,669	0	0	0	0	0	35,669	1,332
1992	34,940	2	0	0	0	0	34,942	1,460
1993	32,521	3	0	0	0	0	32,524	1,452
1994	30,646	0	0	0	0	0	30,646	1,214
1995	28,825	0	0	0	0	0	28,825	1,125
1996	24,797	0	0	0	0	0	24,797	918
1997	23,793	0	0	0	0	0	23,793	818
1998	22,401	0	0	0	0	0	22,401	770
1999	21,918	0	0	0	0	0	21,918	711
2000	20,890	0	0	0	0	0	20,890	727
2001	19,527	0	0	0	0	0	19,527	723
2002	20,676	0	0	0	0	0	20,676	744

Note: Data obtained from summaries rather than directly from original medical records. Total radiation exposure was determined by adding actual exposures for each individual monitored by each reporting command during the year. Total number monitored includes visitors to each reporting command. It is expected that the large effort to compile comparable radiation exposure data from original medical records would show differences no greater than 5 percent.

* Limit in the Naval Nuclear Propulsion Program was changed to 5 rem per year in 1967.

TABLE 3

OCCUPATIONAL RADIATION EXPOSURE RECEIVED BY SHIPYARD PERSONNEL
FROM WORK ASSOCIATED WITH NAVAL NUCLEAR PROPULSION PLANTS

	Number of Persons Monitored Who Received Exposures in the Following Ranges of Rem for the Year						Total Personnel	Total Monitored
	Exposure (Rem)							
Year	**0-1**	**1-2**	**2-3**	**3-4**	**4-5**	**>5***		
1954	508	9	3	5	3	0	528	64
1955	2,563	80	25	6	3	2	2,679	344
1956	2,834	20	5	2	0	1	2,862	162
1957	3,473	97	31	1	2	4	3,608	495
1958	5,766	165	46	10	4	7	5,998	779
1959	10,388	221	133	78	49	23	10,892	1,864
1960	12,047	198	97	22	4	0	12,368	1,158
1961	13,383	198	91	44	14	3	13,733	1,241
1962	14,411	642	366	247	146	108	15,920	5,222
1963	19,164	446	159	71	34	28	19,902	2,725
1964	24,044	804	445	215	144	41	25,693	5,678
1965	22,630	2,306	1,314	814	618	525	28,207	15,829
1966	29,490	2,352	1,623	1,057	1,139	513	36,174	18,804
1967	29,853	2,388	1,563	1,096	733	1	35,634	13,908
1968	30,159	1,344	773	496	279	0	33,051	8,719
1969	25,672	1,790	1,080	753	375	0	29,670	11,077
1970	21,182	2,127	1,382	740	492	0	25,923	13,084
1971	20,041	1,928	1,066	650	240	0	23,925	10,616
1972	17,514	1,692	849	139	5	0	20,199	7,002
1973	13,036	1,403	604	203	6	0	15,252	6,083
1974	12,587	1,464	745	311	50	0	15,157	7,206
1975	12,825	1,116	598	82	42	0	14,663	5,285
1976	13,042	1,268	633	30	0	0	14,973	5,310
1977	13,835	1,277	586	25	0	0	15,723	5,199
1978	13,700	1,016	268	0	0	0	14,984	3,680
1979	15,032	227	7	0	0	0	15,266	2,024
1980	15,287	377	0	0	0	0	15,664	2,402
1981	17,414	304	0	0	0	0	17,718	2,310
1982	19,210	648	0	0	0	0	19,858	3,353
1983	20,407	714	0	0	0	0	21,121	3,506
1984	20,684	502	0	0	0	0	21,186	3,181
1985	20,940	412	0	0	0	0	21,352	2,796
1986	21,186	875	0	0	0	0	22,061	3,495
1987	21,404	788	0	0	0	0	22,192	3,187
1988	20,969	543	0	0	0	0	21,512	2,702
1989	23,789	633	0	0	0	0	24,422	2,941
1990	25,077	501	0	0	0	0	25,578	2,812
1991	24,873	492	0	0	0	0	25,365	2,866
1992	24,703	440	0	0	0	0	25,143	2,936
1993	23,542	572	0	0	0	0	24,114	2,913
1994	18,912	362	0	0	0	0	19,274	1,890
1995	16,422	212	0	0	0	0	16,634	1,355
1996	14,997	80	0	0	0	0	15,077	962
1997	14,501	87	0	0	0	0	14,588	935
1998	14,735	53	0	0	0	0	14,788	882
1999	16,238	60	0	0	0	0	16,298	863
2000	15,617	84	0	0	0	0	15,701	1,009
2001	16,358	84	0	0	0	0	16,442	915
2002	17,887	128	0	0	0	0	18,015	1,087

Note: Data obtained from summaries rather than directly from original medical records. Total radiation exposure was determined by adding actual exposures for each individual monitored by each shipyard during the year. Total number monitored includes visitors to each shipyard. It is expected that the large effort to compile comparable radiation exposure data from original medical records would show differences no greater than 5 percent.
* Limit in the Naval Nuclear Propulsion Program was changed to 5 rem per year in 1967.

FIGURE 2
TOTAL RADIATION EXPOSURE RECEIVED BY SHIPYARD PERSONNEL FROM WORK ON NAVAL NUCLEAR PROPULSION PLANTS 1958 - 2002

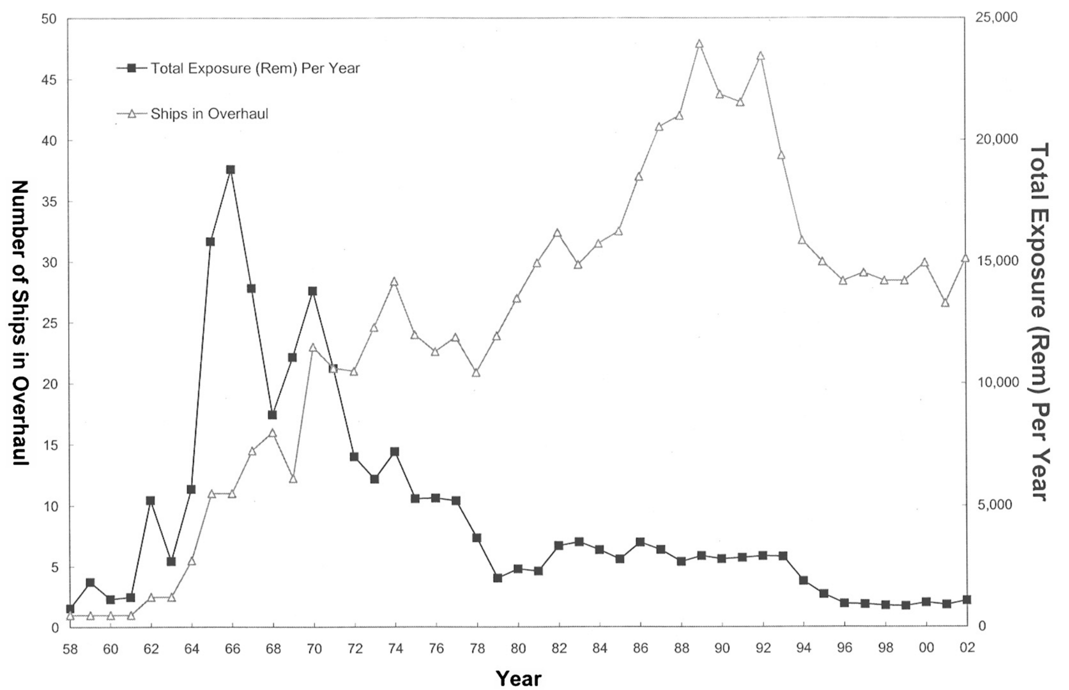

TABLE 4

SHIPYARD AND FLEET DISTRIBUTION
OF PERSONNEL RADIATION EXPOSURE

Year	Average Rem Per Person Monitored		Percent of Personnel Monitored Who Received Greater Than 1 Rem		Number of Personnel Who Exceeded 3 Rem/Quarter
	Fleet	Shipyard	Fleet	Shipyard	
1954	.222	.121	0	3.8	0
1955	.248	.128	10.9	4.3	0
1956	.410	.057	11.5	1.0	0
1957	.199	.137	2.7	3.7	0
1958	.174	.130	2.4	3.9	0
1959	.180	.171	4.7	4.6	8
1960	.138	.094	7.5	2.6	0
1961	.137	.090	2.9	2.5	0
1962	.185	.328	4.3	9.5	9
1963	.150	.137	2.7	3.7	2
1964	.182	.221	4.5	6.4	4
1965	.266	.561	7.5	19.8	5
1966	.186	.520	4.6	18.5	6
1967	.143	.390	2.5	16.2	3
1968	.100	.264	2.0	8.8	0
1969	.105	.373	2.7	13.5	0
1970	.114	.505	2.9	18.3	0
1971	.122	.444	2.7	16.2	0
1972	.096	.347	2.3	13.3	0
1973	.100	.399	2.3	14.5	0
1974	.114	.475	2.0	17.0	0
1975	.123	.360	2.0	12.5	0
1976	.145	.355	2.4	12.9	0
1977	.136	.331	2.3	12.0	0
1978	.100	.246	1.4	8.5	0
1979	.072	.133	0.4	1.5	0
1980	.068	.153	0.4	2.4	0
1981	.059	.130	0.1	1.7	0
1982	.060	.169	0.2	3.3	0
1983	.066	.166	0.2	3.4	0
1984	.057	.150	0.0	2.4	0
1985	.049	.131	0.1	1.9	0
1986	.047	.158	0.0	4.0	0
1987	.044	.144	0.0	3.6	0
1988	.041	.126	0.0	2.5	0
1989	.045	.120	0.1	2.6	0
1990	.042	.110	0.0	2.0	0
1991	.037	.113	0.0	1.9	0
1992	.042	.117	0.0	1.8	0
1993	.045	.121	0.0	2.4	0
1994	.040	.098	0.0	1.9	0
1995	.039	.081	0.0	1.3	0
1996	.037	.064	0.0	0.5	0
1997	.034	.064	0.0	0.6	0
1998	.034	.060	0.0	0.4	0
1999	.032	.053	0.0	0.4	0
2000	.035	.064	0.0	0.5	0
2001	.037	.056	0.0	0.5	0
2002	.036	.060	0.0	0.7	0
Average	.075	.226	1.0	6.9	
NNPP AVERAGE	0.145		3.8		

Table 5 provides information on the distribution of lifetime accumulated exposures for all personnel who were monitored in 2002 for radiation exposure associated with naval nuclear propulsion plants. The 5 rem annual Federal radiation exposure limit would allow accumulating 100 rem in 20 years of work, or 200 rem in 40 years. The fact that no one shown in Table 5 comes close to having accumulated this much radiation exposure is the result of deliberate efforts to keep lifetime radiation exposures low.

TABLE 5

DISTRIBUTION OF TOTAL LIFETIME RADIATION EXPOSURE ASSOCIATED WITH NAVAL NUCLEAR PROPULSION PLANTS

Range of Accumulated Lifetime Radiation Exposures (Rem)	Percentage of Personnel Monitored in 2002 With Lifetime Accumulated Radiation Exposure Within that Range	
	FLEET	SHIPYARDS
0 – 5	99.87	90.65
5 – 10	0.11	7.03
10 – 15	0.02	1.62
15 – 20	0	0.48
20 – 25	0	0.10
25 – 30	0	0.07
30 – 40	0	0.03
40 – 60	0	0
> 60	0	0

The Federal radiation exposure limits used in the U.S. until the 1994 change to the Code of Federal Regulations, Title 10, Part 20, limited an individual's lifetime exposure to 5 rem for each year beyond age 18. With the recent change, lifetime exposure is not specifically limited, but is controlled as the result of the annual limit of 5 rem. In their most recent radiation protection recommendations, the National Council on Radiation Protection and Measurements (NCRP) recommends organizations control lifetime accumulated exposure to less than 1 rem times the person's age (reference 12). Among all personnel monitored in 2002, there is currently no worker with a lifetime accumulated exposure greater than the NCRP recommended level of 1 rem times his or her age from radiation associated with naval nuclear propulsion plants.

Table 6 provides a basis for comparison between the radiation exposure for light water reactors operated by the Navy and commercial nuclear-powered reactors licensed by the Nuclear Regulatory Commission. The 2001 data in this Nuclear Regulatory Commission table cover 104 licensed commercial nuclear-powered reactors with a total of 11,109 rem (reference 13). The 2001 average annual exposure of each worker at commercial nuclear-powered reactors was 0.106 rem. Licensees of commercial nuclear-powered reactors reported 279 overexposures to external radiation during the years 1971 through 2001. Numbers in excess of 5 rem are not necessarily overexposures; prior to January 1, 1994, Nuclear Regulatory Commission regulations permitted exposures of 3 rem each quarter up to 12 rem per year within the accumulated total limit of 5 rem for each year of a person's age beyond 18.

TABLE 6

PERSONNEL RADIATION EXPOSURE FOR COMMERCIAL NUCLEAR-POWERED REACTORS
LICENSED BY THE U.S. NUCLEAR REGULATORY COMMISSION

SUMMARY OF ANNUAL WHOLE BODY EXPOSURE BY INCREMENT

YEAR	TOTAL MONITORED	NOT MEASURABLE	NUMBER OF INDIVIDUALS BY EXPOSURE INCREMENT - REM											TOTAL MAN-REM	NUMBER OF OVER-EXPOSURES
			0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	>10		
1971	9,581	8,996			315	137	105	17	11	0	0	0	0		2
1972	15,713	14,783			532	199	111	46	21	9	6	6	0		16
1973	33,823	19,043	9,798	2,468	1,584	422	251	125	71	38	16	7	0	13,963	19
1974	38,938	20,472	13,766	2,503	1,378	471	226	86	30	6	0	0	0	13,722	43
1975	44,343	18,854	18,289	3,948	1,872	691	423	169	60	24	12	0	1	20,879	14
1976	61,151	25,704	26,636	4,880	2,354	789	487	188	70	26	11	5	1	26,433	20
1977	61,673	22,688	28,165	5,660	2,858	1,290	661	186	89	47	23	6	0	32,521	27
1978	69,137	26,360	31,873	5,984	3,050	1,194	517	110	37	9	0	1	2	31,785	9
1979	100,834	40,535	47,196	7,574	3,401	1,403	545	117	42	17	3	1	0	39,908	23
1980	119,345	44,716	56,312	10,672	4,607	1,816	831	235	119	29	7	1	0	53,739	73
1981	116,030	39,258	58,047	11,174	4,809	1,999	533	103	93	9	3	1	1	54,163	7
1982	121,013	41,704	61,576	10,220	4,716	2,066	596	97	31	5	0	1	1	52,201	2
1983	126,736	47,027	59,878	11,342	5,334	2,266	716	121	38	8	2	0	0	56,484	8
1984	145,157	54,637	71,345	11,284	5,208	2,122	487	52	22	0	0	0	0	55,251	3
1985	146,551	59,625	72,150	10,042	3,574	1,002	157	1	0	0	0	0	0	43,048	3
1986	161,656	67,677	79,662	10,241	3,062	868	146	0	0	0	0	0	0	42,386	1
1987	181,401	85,170	82,882	10,611	2,192	477	69	0	0	0	0	0	0	40,400	1
1988	183,294	87,281	82,723	10,310	2,442	511	26	0	1	0	0	0	0	40,772	6
1989	184,038	83,954	89,432	8,633	1,615	370	34	0	0	0	0	0	0	35,931	1
1990	182,442	83,875	87,824	8,594	1,791	337	21	0	0	0	0	0	0	36,602	0
1991	178,333	87,247	83,935	5,977	938	219	17	0	0	0	0	0	0	28,519	0
1992	181,889	87,717	87,198	6,076	808	85	4	0	0	0	0	0	0	29,297	1
1993	169,259	83,066	80,152	5,322	638	76	5	0	0	0	0	0	0	26,364	0
1994	139,390	67,777	66,823	4,242	508	40	0	0	0	0	0	0	0	21,704	0
1995	132,266	61,445	66,179	3,912	595	133	2	0	0	0	0	0	0	21,688	0
1996	126,402	58,097	64,634	3,196	408	67	0	0	0	0	0	0	0	18,883	0
1997	126,781	58,409	65,446	2,599	286	41	0	0	0	0	0	0	0	17,149	0
1998	114,367	56,901	55,444	1,827	179	15	1	0	0	0	0	0	0	13,187	0
1999	114,154	54,938	57,043	1,908	247	18	0	0	0	0	0	0	0	13,666	0
2000	110,557	53,324	55,295	1,734	186	18	0	0	0	0	0	0	0	12,652	0
2001	104,928	52,636	50,626	1,392	221	53	0	0	0	0	0	0	0	11,109	0

Figures shown for the years 1977-2001 have been adjusted by the NRC for the multiple reporting of transient individuals.

INTERNAL RADIOACTIVITY

Policy and Limits

The Navy's policy on internal radioactivity for personnel associated with the Naval Nuclear Propulsion Program continues to be the same as it was more than four decades ago—to prevent significant radiation exposure to personnel from internal radioactivity. The limits invoked to achieve this objective are one-tenth of the levels allowed by Federal regulations for radiation workers. The results of this program have been that since 1962, no one has received more than one-tenth the Federal annual internal occupational exposure limits from internal radiation exposure caused by radioactivity associated with naval nuclear propulsion plants[6].

Prior to 1994, the basic Federal limit for radiation exposure to organs of the body from internal radioactivity was 15 rem per year. There have been higher levels applied at various times for thyroid and for bones; however, use of these specific higher limits was not necessary in the Naval Nuclear Propulsion Program.

The limit recommended for most organs of the body by the U.S. National Committee on Radiation Protection and Measurements in 1954 (reference 1), by the U.S. Atomic Energy Commission in the initial edition of reference (3) applicable in 1957, and by the International Commission on Radiological Protection in 1959 (reference 2) was 15 rem per year. This limit was adopted for Federal agencies when President Eisenhower approved recommendations of the Federal Radiation Council May 13, 1960.

In 1977, the International Commission on Radiological Protection revised its recommendations (reference 8), particularly regarding internal exposure. The new recommendations provided a method of combining, and controlling, exposure from internal radioactivity with exposure from external radiation. The effect of the 1977 recommendations was to raise the allowable dose to many organs, with no organ allowed to receive more than 50 rem in a year. In conjunction with these recommendations, more recent knowledge on the behavior and effect of internal radioactivity was used to derive new limits for its control (reference 14). The Federal guidance approved by the President in 1987 adopted these revised recommendations and methods, and were incorporated as Federal limits in 1994. As discussed below, cobalt-60 is the radionuclide of most concern for internal radioactivity in the Naval Nuclear Propulsion Program. The derived airborne radioactivity concentration limits for cobalt-60 established at the inception of the Program, which control exposure to below one-tenth the Federal annual internal occupational exposure limit, remain unchanged under the new recommendations and methodology.

Source of Radioactivity

Radioactivity can get inside the body through air, through water or food, and through surface contamination via the mouth, skin, or a wound. The radioactivity of primary concern is the activated metallic corrosion products on the inside surfaces of reactor plant piping systems. These are in the form of insoluble metallic oxides, primarily iron oxides. Reference 15 contains more details on why cobalt-60 is the radionuclide of most concern for internal radioactivity.

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6 Previous reports stated that no one had received more than one-tenth the Federal annual internal occupational exposure limit from internal radiation exposure caused by radioactivity associated with naval nuclear propulsion plants since 1960. During recent records reviews of occupational radiation exposure at Portsmouth Naval Shipyard, it was identified that, in 1962, one individual exceeded one-tenth the Federal annual internal exposure limit of 15 rem in effect at the time. The committed dose to the individual's lungs was 5.45 rem.

The design conditions for reactor fuel are much more severe for warships than for commercial power reactors. As a result of being designed to withstand shock, naval reactor fuel elements retain fission products including fission gases within the fuel. Sensitive measurements are frequently made to verify the integrity of reactor fuel. Consequently, fission products such as strontium-90 and cesium-137 make no measurable contribution to internal exposure of personnel from radioactivity associated with naval nuclear propulsion plants. Similarly, alpha emitters such as uranium and plutonium are retained within the fuel elements and are not accessible to personnel operating or maintaining a naval nuclear propulsion plant.

Because of the high integrity of reactor fuel and because soluble boron is not used in reactor coolant for normal reactivity control in naval nuclear propulsion plants, the amount of tritium in reactor coolant is far less than in typical commercial power reactors. The small amount that is present is formed primarily as a result of neutron interaction with the deuterium naturally present in water. The radiation from tritium is of such low energy that the Federal limits for breathing or swallowing tritium are more than 300 times higher than for cobalt-60. As a result, radiation exposure to personnel from tritium is far too low to measure. Similarly, the low-energy beta radiation from carbon-14, which is formed in small quantities in reactor coolant systems as a result of neutron interactions with nitrogen and oxygen, does not add measurable radiation exposure to personnel operating or maintaining naval nuclear propulsion plants.

Control of Airborne Radioactivity

Airborne radioactivity is controlled in maintenance operations such that respiratory equipment is not normally required. To prevent exposure of personnel to airborne radioactivity when work might release radioactivity to the atmosphere, contamination containment tents or bags are used. These containments are ventilated to the atmosphere through high efficiency filters that have been tested to remove at least 99.95 percent of particles of a size comparable to cigarette smoke. Radiologically controlled areas such as reactor compartments are also required to be ventilated through high efficiency filters anytime work that could cause airborne radioactivity is in progress. Airborne radioactivity surveys are required to be performed regularly in radioactive work areas. Anytime airborne radioactivity above the limit is detected in occupied areas, work that might be causing airborne radioactivity is stopped. This conservative action is taken to minimize internal radioactivity even though the Naval Nuclear Propulsion Program's airborne radioactivity limit would allow continuous breathing for 40 hours per week throughout the year to reach an annual exposure to the lungs of one-tenth the Federal limit. Personnel are also trained to use respiratory equipment when airborne radioactivity above the limit is detected. However, respiratory equipment is seldom needed and is not relied upon as the first line of defense against airborne radioactivity.

It is not uncommon for airborne radioactivity to be caused by radon naturally present in the air. Atmospheric temperature inversion conditions can allow the buildup of radioactive particles from radon. Radon can also build up in sealed or poorly ventilated rooms in homes or buildings made of stone or concrete, or it can migrate from the supporting ground. In fact, most cases of airborne radioactivity above the Naval Nuclear Propulsion Program's conservative airborne radioactivity limit in occupied areas have been caused by radioactive particles from atmospheric radon, which has a higher airborne concentration limit, and not from the reactor plant. Procedures have been developed to reduce the radon levels when necessary and to allow work to continue after it has been determined that the elevated airborne radioactivity is from naturally occurring radon.

Radon is also emitted from radium used for making dials luminous. There have been a number of cases where a single radium dial (such as on a wristwatch) has caused the

entire atmosphere of a submarine to exceed the airborne radioactivity limit used for the nuclear propulsion plant. As a result, radium in any form was banned from submarines to prevent interference with keeping airborne radioactivity from the nuclear propulsion plant as low as practicable.

Control of Radioactive Surface Contamination

Perhaps the most restrictive regulations in the Naval Nuclear Propulsion Program's radiological controls program are for controlling radioactive contamination. Work operations involving potential for spreading radioactive contamination use containments to prevent personnel contamination or the generation of airborne radioactivity. The controls for radioactive contamination are so strict that precautions sometimes have had to be taken to prevent tracking contamination from the world's atmospheric fallout and natural sources outside radiological areas *into* radiological spaces because the contamination control limits used in the nuclear areas were below the levels of fallout and natural contamination occurring outside in the general public areas.

Anticontamination clothing, including coveralls, hoods (to cover the head, ears and neck), shoe covers and gloves, is provided when needed. However, the basic approach is to avoid the need for anticontamination clothing by containing the radioactivity. As a result, most work on radioactive materials is performed with hands reaching into gloves installed in containments, making it unnecessary for the worker to wear anticontamination clothing. In addition to providing better control over the spread of radioactivity, this method has reduced radiation exposure since the worker can usually do a job better and faster in normal work clothing. A basic requirement of contamination control is to monitor all personnel leaving any area where radioactive contamination could possibly occur. Workers are trained to survey themselves (i.e., frisk), and their performance is checked by radiological controls personnel. Frisking of the entire body is required, normally using sensitive hand-held survey instruments. Major work facilities are equipped with portal monitors, which are used in lieu of hand-held friskers. Personnel monitor before, not after, they wash. Therefore, washing or showering at the exit of radioactive work areas is not required. The basic philosophy is to prevent contamination, not wash it away.

Trained radiological controls personnel frequently survey for radioactive contamination. These surveys are reviewed by supervisory personnel to provide a doublecheck that no abnormal conditions exist. The instruments used for these surveys are checked against a radioactive calibration source daily and prior to use, and they are calibrated at least every 6 months.

Control of Food and Water

Smoking, eating, drinking, and chewing are prohibited in radioactive areas. Aboard ship, drinking water is made from seawater, in some cases by distilling seawater using steam from the secondary plant steam system. However, the steam is not radioactive, because it is in a secondary piping system separate from the reactor plant radioactive water. In the event radioactivity were to leak into the steam system, sensitive radioactivity detection instruments (which operate continuously) would give early warning.

Wounds

Skin conditions or open wounds that might not readily be decontaminated are cause for temporary or permanent disqualification from doing radioactive work. Workers are trained to report such conditions to radiological controls or medical personnel, and radiological controls technicians watch for open wounds when workers enter radioactive work areas. In the initial medical examination prior to radiation work and during

subsequent examinations, skin conditions are also checked. If the cognizant local medical officer determines that a wound is sufficiently healed or considers that the wound is adequately protected, he may remove the temporary disqualification.

There have been only a few cases of contaminated wounds in the Naval Nuclear Propulsion Program. In most years, none occurred. Examples of such injuries that have occurred in the past include a scratched hand, a metallic sliver in a hand, a cut finger, and a puncture wound to a hand. These wounds occurred at the same time the person became contaminated. Insoluble metallic oxides that make up the radioactive contamination remain primarily at the wound rather than being absorbed into the bloodstream. These radioactively contaminated wounds have been easily decontaminated. No case of a contaminated wound is known where the radioactivity present in the wound was as much as 0.1 percent of that permitted for a radiation worker to have in his or her body.

Monitoring for Internal Radioactivity

The radioactivity of most concern for internal radiation exposure from naval nuclear propulsion plants is cobalt-60. Although most radiation exposure from cobalt-60 inside the body will be from beta radiation, the gamma radiation given off makes cobalt-60 easy to detect. Complex whole body counters are not required to detect cobalt-60 at low levels inside the body. For example, one-millionth of a curie of cobalt-60 inside the lungs or intestines will cause a measurement of two times above the background reading with the standard hand-held survey instrument used for personnel frisking. This amount of internal radioactivity will cause the instrument to reach the alarm level. Every person is required to monitor the entire body upon leaving an area with radioactive surface contamination. Monitoring the entire body (not just the hands and feet) is a requirement in the Naval Nuclear Propulsion Program. Therefore, if a person had as little as one-millionth of a curie of cobalt-60 internally, it would readily be detected.

Swallowing one-millionth of a curie of cobalt-60 will cause internal radiation exposure to the gastro-intestinal tract of about 0.08 rem. The radioactivity will pass through the body and be excreted within a period of a little more than a day. Since 1994, Federal regulations limit organ exposure from internal radioactivity to 50 rem per year.

One-millionth of a curie of cobalt-60 still remaining in the lungs 1 day after an inhalation incident is estimated to cause a radiation exposure of about 2 rem to the lungs over the following year and 6 rem total over a lifetime, based on standard calculations recommended by the International Commission on Radiological Protection (reference 14). Since 1994, Federal regulations limit organ exposure from internal radioactivity to 50 rem per year. These techniques provide a convenient way to estimate the amount of radiation exposure a typical individual might be expected to receive from small amounts of internally deposited radioactivity. These techniques account for the gradual removal of cobalt-60 from the lungs through biological processes and the radioactive decay of cobalt-60 with a 5.3 year half-life. However, if an actual case were to occur, the measured biological elimination rate would be used in determining the amount of radiation exposure received.

In addition to the control measures to prevent internal radioactivity and the frisking frequently performed by those who work with radioactive materials, more sensitive internal monitoring is also performed. Procedures designed specifically for monitoring internal radioactivity use a type of gamma radiation scintillation detector, that will reliably detect inside the body an amount of cobalt-60 that is more than 100 times lower than the one-millionth of a curie used in the examples above. Shipyards typically monitor each employee for internal radioactivity as part of each radiation medical examination, which is given before initially performing radiation work, after terminating radiation work, and periodically in between. Tenders, bases, and nuclear-powered

ships require personnel to be internally monitored before initially assuming duties involving radiation exposure and upon terminating from such duties.

During the year, shipyards, tenders, and bases also periodically monitor groups of personnel who did the work most likely to have caused spread of radioactive contamination. Any person—whether at a shipyard, tender, base, or aboard a nuclear-powered ship—who has radioactive contamination above the limit anywhere on the skin during regular monitoring at the exit from a radioactive area is monitored for internal radioactivity with the sensitive detector. Also, any person who might have breathed airborne radioactivity above limits is monitored with the sensitive detector.

Internal monitoring equipment is calibrated each day the equipment is in use. This calibration involves checking the equipment's response to a known source of radiation. In addition, the Navy has an independent quality assurance program in which organizations performing internal monitoring are tested periodically. This testing involves monitoring a human-equivalent torso phantom, which contains an amount of radioactivity traceable to standards maintained by the National Institute of Standards and Technology. The exact amount of radioactivity in the test phantom is not divulged to the organization being tested until after the test is complete. Any inaccuracies found by these tests that exceed established permissible error limits are investigated and corrected.

Results of Internal Monitoring in 2002

During 2002, 7,581 personnel were monitored for internally deposited radioactivity associated with naval nuclear propulsion plants. Equipment and procedures provide detection of at least 0.01 millionths of a curie of cobalt-60. No personnel monitored during 2002 had internal radioactivity above this level.

EFFECTS OF RADIATION ON PERSONNEL

Control of radiation exposure in the Naval Nuclear Propulsion Program has always been based on the assumption that any exposure, no matter how small, involves some risk; however, exposure within the accepted exposure limits represents a risk small in comparison with the normal hazards of life. The basis for this statement is presented below.

Exposure to Radiation May Involve Some Risk

Since the inception of nuclear power, scientists have cautioned that exposure to ionizing radiation in addition to that from natural background may involve some risk. The National Committee on Radiation Protection and Measurements in 1954 (reference 1) and the International Commission on Radiological Protection in 1958 (reference 2) both recommended that exposures should be kept as low as practicable and that unnecessary exposure should be avoided to minimize this risk. The International Commission on Radiological Protection in 1962 (reference 16) explained the assumed risk as follows:

> The basis of the Commission's recommendations is that any exposure to radiation may carry some risk. The assumption has been made that, down to the lowest levels of dose, the risk of inducing disease or disability in an individual increases with the dose accumulated by the individual, but is small even at the maximum permissible levels recommended for occupational exposure.

The National Academy of Sciences-National Research Council Advisory Committee on the Biological Effects of Atomic Radiation included similar statements in its reports in the 1956-1961 period and most recently in 1990 (reference 17). In 1960, the Federal Radiation Council stated (reference 4) that its radiation protection guidance did not differ substantially from recommendations of the National Committee on Radiation Protection and Measurements, the International Commission on Radiological Protection, and the National Academy of Sciences. This statement was again reaffirmed in 1987 (reference 9).

One conclusion from these reports is that radiation exposures to personnel should be minimized, but this is not a new conclusion. It has been a major driving force of the Naval Nuclear Propulsion Program.

Radiation Exposure Comparisons

The success of the Naval Nuclear Propulsion Program in minimizing exposures to personnel can be evaluated by making some radiation exposure comparisons.

Annual Exposure

One important measure of personnel exposure is the amount of exposure an individual receives in a year. Tables 2 and 3 show that since 1980, no individual has exceeded 2 rem in a year while working in the Naval Nuclear Propulsion Program. Also, from Table 4 it can be seen that the average exposure per person monitored has been on a downward trend the last 16 years and averaged approximately 0.044 rem for Fleet personnel and 0.112 rem for shipyard personnel since 1980. Fleet personnel monitored in 2002 received an average of 0.036 rem, while shipyard personnel received an average of 0.060 rem for this year. The following comparisons give perspective on these individual annual doses in comparison to Federal limits and other exposures:

- The Naval Nuclear Propulsion Program limits an individual's dose to 3 rem in one ***quarter***. No one in the Naval Nuclear Propulsion Program has exceeded 2 rem in one ***year*** since 1980--less than half the Federal annual limit of 5 rem.

- No one in the Naval Nuclear Propulsion Program has exceeded 2 rem in a year since 1980. Annually between 195 and 7,500 workers at NRC-licensed commercial nuclear-powered reactors have exceeded 2 rem in various years over this same period (reference 13).

- The average annual exposure of 0.044 rem since 1980 for Fleet personnel is:

  - less than one percent of the Federal annual limit of 5 rem.

  - approximately one-third the average annual exposure of commercial nuclear power plant personnel (reference 13).

  - approximately one-fourth the average annual exposure received by U.S. commercial airline flight crew personnel due to cosmic radiation (reference 18).

- The average annual exposure of 0.112 rem since 1980 for shipyard personnel is:

  - approximately two percent of the Federal annual limit of 5 rem.

  - equal to the average annual exposure of commercial nuclear power plant personnel (reference 13).

  - less than the average annual exposure received by U.S. commercial airline flight crew personnel due to cosmic radiation (reference 18).

For additional perspective, the annual exposures for personnel in the Naval Nuclear Propulsion Program may also be compared to natural background and medical exposures:

- The maximum annual exposure of 2 rem is less than half the annual exposure from natural radioactivity in the soils in some places in the world, such as Tamil Nadu, India, and Meaipe, Brazil (reference 17).

- The average annual exposure of 0.044 rem since 1980 for Fleet personnel is:

  - less than 15 percent of the average annual exposure to a member of the population in the U.S. from natural background radiation (reference 22).

  - less than the difference in the annual exposure due to natural background radiation between Denver, Colorado, and Washington, D.C. (reference 22).

- Fleet personnel operating nuclear-powered submarines receive less total annual exposure than they would if they were stationed on shore performing work not involving occupational radiation exposure. This exposure is less because of the low natural background radiation in a steel hull submerged in the ocean compared to the natural background radiation from cosmic, terrestrial, and radon sources on shore (and the effectiveness of the shielding aboard ship).

- The average annual exposure of 0.112 rem since 1980 for shipyard personnel is:

  - less than half the average annual exposure to a member of the population in the U.S. from natural background radiation (reference 22).

- less than the exposure from common diagnostic medical x-ray procedures such as an x-ray of the back (reference 23).

Collective Dose

The sum of all individual exposures gives the collective dose. Collective dose is used as a measure of the theoretical effect on the personnel occupationally exposed from the Naval Nuclear Propulsion Program taken as a group, and is an indicator of the effectiveness of the Program's efforts to minimize radiation exposure. From Tables 2 and 3, it can be seen that the collective dose received by all personnel in the Naval Nuclear Propulsion Program in 2002 was 1,831 rem. The following comparisons give perspective on this collective dose in comparison to collective doses from other occupations. This annual collective dose is:

- less than half the average annual collective dose received by a comparable number of commercial nuclear power plant personnel (reference 13).

- less than the average annual collective dose received by a comparable number of persons in the medical field (reference 18).

- approximately one-fourth the average annual collective dose received by a comparable number of commercial airline flight crew personnel (reference 18).

For even further perspective, the annual collective dose received by personnel in the Naval Nuclear Propulsion Program may also be compared to collective doses from radiation exposures not related to an individual's occupation. This annual collective dose is:

- approximately 15 percent of the average annual collective dose of 11,607 rem received by a comparable number of individuals in the U.S. population due to natural background radiation (reference 11).

- approximately one-third the average annual collective dose of 5,030 rem received by a comparable number of individuals in the U.S. population from diagnostic medical procedures such as x-rays of the back (reference 23).

- less than four percent of the average annual collective dose of 50,298 rem received by a comparable number of individuals in the U.S. population due to the natural radioactivity in tobacco smoke (reference 11) (rough comparison due to the difficulty in estimating the average annual collective dose received from smoking).

Conclusions on Radiation Exposure to Personnel

The preceding comparisons show that occupational exposures to individuals working in the Naval Nuclear Propulsion Program are small when compared to other occupational exposures and limits and are within the range of exposures from natural background radiation in the U.S. and worldwide. Additionally, the total dose to all persons (collective dose) each year is small compared to the collective doses to workers in other occupations, and insignificant compared to the collective doses to the U.S. population from natural background radiation, medical procedures, and tobacco smoke. In reference 18 the National Council on Radiation Protection and Measurements reviewed the exposures to the U.S. working population from occupational exposures. This included a review of the occupational exposures to personnel from the Naval Nuclear Propulsion Program. Based on this review, the National Council on Radiation Protection and Measurements concluded:

> These small values [of occupational exposure] reflect the success of the Navy's efforts to keep doses as low as reasonably achievable (ALARA).

Studies of the Effects of Radiation on Human Beings

Observations on the biological effects of ionizing radiation began soon after the discovery of x-rays in 1895 (reference 17).

Numerous references are made in the early literature concerning the potential biological effects of exposure to ionizing radiation. These effects have been intensively investigated for many years (reference 24). Although there still exists some uncertainty about the exact level of risk, the National Academy of Sciences has stated in reference 25:

> It is fair to say that we have more scientific evidence on the hazards of ionizing radiation than on most, if not all, other environmental agents that affect the general public.

A large amount of experimental evidence of radiation effects on living systems has come from laboratory studies on cell systems and on animals. However, what sets our extensive knowledge of radiation effects on human beings apart from other hazards is the evidence that has been obtained from studies of human populations that have been exposed to radiation in various ways (reference 25). The health effects demonstrated from studies of people exposed to high doses of radiation (that is, significantly higher than current occupational limits) include the induction of cancer, cataracts, sterility, and developmental abnormalities from prenatal exposure. Animal studies have also documented the potential for genetic effects.

Near the end of 1993, the Secretary of Energy requested the disclosure of all records and information on radiation experiments involving human subjects performed or supported by Department of Energy or predecessor agencies. The Naval Nuclear Propulsion Program has never conducted or supported any radiation experiments on human beings. As discussed in this report, the Program has adopted exposure limits recommended by national and international radiation protection standards committees (such as the National Council on Radiation Protection and Measurements, and the International Commission on Radiological Protection) and has relied upon conservative designs and disciplined operating and maintenance practices to minimize radiation exposure to levels well below these limits.

High-Dose Studies

The human study populations that have contributed a large amount of information about the biological effects of radiation exposure include the survivors of the atomic bombings of Hiroshima and Nagasaki, x-rayed tuberculosis patients, victims of various radiation accidents, patients that have received radiation treatment for a variety of diseases, radium-dial painters, and inhabitants of South Pacific islands that received unexpected doses from fallout due to early nuclear weapons tests. All of these populations received high or very high exposures.

The studies of atomic bomb survivors have provided the single most important source of information on the immediate and delayed effects of whole body exposure to ionizing radiation. The studies have been supported for over 50 years by the U.S. and Japanese Governments and include analysis of the health of approximately 90,000 survivors of the bombings. Continued followup of the Japanese survivors has changed the emphasis of concern from genetic effects to the induction of cancer (references 17 and 19).

The induction of cancer has been the major latent effect of radiation exposure in the atomic bomb survivors. The tissues most sensitive to the induction of cancer appear to be the blood-forming organs, the thyroid, and the female breast. Other cancers linked to radiation, but with a lower induction rate, include cancers of the lung, stomach, colon, bladder, liver, and ovary. A wave-like pattern of leukemia induction was seen over time beginning approximately 2 years after exposure, peaking within 10 years of exposure, and generally diminishing to near baseline levels over the next 40 years. For other cancers, a statistically significant excess was observed 5-10 years or more after exposure, and the excess risk continues to rise slowly with time (reference 19).

While it is often stated that radiation causes all forms of cancer, many forms of cancer actually show no statistically significant increase among atomic bomb survivors. These cancers include chronic lymphocytic leukemia, multiple myeloma, and cancers of the rectum, gall bladder, pancreas, larynx, prostate, cervix, and kidney (reference 19).

To understand the impact of cancer induction from the atomic bombings in 1945, it is necessary to compare the number of radiation-related cancers to the total number of cancers expected in the exposed group. In studies of approximately 50,000 survivors with doses ranging from 0.5 to over 200 rem, approximately 6,900 cases of solid cancer have been identified as of 1994. Of these, roughly 700 are in excess of expectation (reference 20). Also, within this population, there were 4,565 solid cancer deaths and 176 leukemia deaths as of 1990 (reference 21). Of these, an estimated 376 solid cancer deaths and 78 leukemia deaths are in excess of expectation (reference 21). These studies did not reveal a statistically significant excess of cancer below doses of 6 rem (reference 19). The cancer mortality experience of the other human study populations exposed to high doses (referenced above) is generally consistent with the experience of the Japanese atomic bomb survivors (reference 19).

About 40 years ago, the major concern of the effects from radiation exposure centered on possible genetic changes. Ionizing radiation was known to cause such changes in many species of plants and animals. However, intense study of nearly 70,000 offspring of atomic bomb survivors has failed to identify any increase in genetic effects. Based on a recent analysis, human beings now appear less sensitive to the genetic effects from radiation exposure than previously thought (reference 17).

Radiation induced cataracts have been observed in atomic bomb survivors and persons treated with very high doses of x-rays to the eye. Based on this observation, potential cataract induction was a matter of concern. However, more recent research indicates that the induction of cataracts by radiation requires a high threshold dose. The National Academy of Sciences has stated that unless the protracted exposure to the eye exceeds the threshold of 800 rem, vision-impairing cataracts will not form. This exposure greatly exceeds the amount of radiation that can be accumulated by the lens through occupational exposure to radiation under normal working conditions (reference 17).

Radiation damage to the reproduction cells at very high doses has been observed to result in sterility. Impairment of fertility requires a dose large enough to damage or deplete most of the reproductive cells and is close to a lethal dose if exposure is to the whole body. The National Academy of Sciences estimates the threshold dose necessary to induce sterility in the male, or female, is approximately 350 rem, or possibly more, in a single dose (reference 17). As in the case of cataract induction, this dose far exceeds the dose that can be received from occupational exposure under normal working conditions.

Among the atomic bomb survivors' children who received high prenatal exposure (that is, their mothers were pregnant at the time of the exposure), developmental

abnormalities were observed. These abnormalities included stunted growth, small head size, and mental retardation. Additionally, recent analysis suggests that during a certain stage of development (the 8th to 15th week of pregnancy) the developing brain appears to be especially sensitive to radiation. A slight lowering of IQ might follow even relatively low doses of 10 rem or more (reference 17).

From this discussion of the health effects observed in studies of human populations exposed to high doses of radiation, it can be seen that the most important of the effects from the standpoint of occupationally exposed workers is the potential for induction of cancer (reference 17).

Low-Dose Studies

The cancer-causing effects of radiation on the bone marrow, female breast, thyroid, lung, stomach, and other organs reported for the atomic bomb survivors are similar to findings reported for other irradiated human populations. With few exceptions, however, the effects have been observed only at high doses and high dose rates. Studies of populations chronically exposed to low-level radiation have not shown consistent or conclusive evidence of an associated increase in the risk of cancer (reference 17). Attempts to observe increased cancer in human population exposed to low doses of radiation have been difficult.

One problem in such studies is the number of people needed to provide sufficient statistics. As the dose to the exposed group decreases, the number of people needed to detect an increase in cancer goes up at an accelerated rate. For example, for a group exposed to 1 rem (equivalent to the average lifetime accumulated dose in the Naval Nuclear Propulsion Program), it would take more than 500,000 people in order to detect an excess in lung cancers (based on current estimates of the risk [reference 26]). This is more than 2½ times the number of persons that have performed nuclear work in all the naval shipyards over the last 49 years. Another limiting factor is the relatively short time since low-dose occupational exposure started being received by large groups of people. As discussed previously, data from the atomic bomb survivors indicate a long latency period between the time of exposure and expression of the disease.

There is also the compounding factor that cancer is a generalization for a group of approximately 300 separate diseases, many being relatively rare and having different apparent causes. With low-dose study data, it is difficult to eliminate the possibility that some factor other than radiation may be causing an apparent increase in cancer induction. This difficulty is particularly apparent in studies of lung cancer, for example, where smoking is (a) such a common exposure, (b) poorly documented as to individual habits, and (c) by far the primary cause of lung cancer. Because cancer induction is statistical in nature, low-dose studies are limited by the fact that an apparent observed small increase in a cancer may be due to chance alone.

Despite the above-mentioned problems, and the lack of consistent or conclusive evidence from such studies to date, low-dose studies fulfill an important function. They are the only means available for eventually testing the validity of current risk estimates derived from data accumulated at higher doses and higher dose rates.

Low-dose groups that have been, and are currently being, studied include groups exposed as a result of medical procedures; exposed to fallout from nuclear weapons testing; living near nuclear installations; living in areas of high natural background radiation; and occupationally exposed to low doses of radiation. The National Academy of Sciences has reviewed a number of the low dose studies in references 17 and 25. Their overall conclusion from reviewing these studies was:

> Studies of populations chronically exposed to low-level radiation, such as those residing in regions of elevated natural background radiation, have not shown consistent or conclusive evidence of an associated increase in the risk of cancer. (reference 17)

This conclusion has been supported by studies that have been completed since reference 17 was published. For example, in 1990 the National Cancer Institute completed a study of cancer in U.S. populations living near 62 nuclear facilities that have been in operation prior to 1982. This study included commercial nuclear power plants and Department of Energy facilities that handle radioactive materials. The conclusion of the National Cancer Institute study was:

> There was no evidence to suggest that the occurrence of leukemia or any other form of cancer was generally higher in the [counties near the nuclear facilities] than in the [counties remote from nuclear facilities]. (reference 27)

At the request of the Three Mile Island Public Health Fund, independent researchers investigated whether the pattern of cancer in the 10-mile area surrounding the Three Mile Island nuclear plant had changed after the TMI-2 accident in March 1979 and, if so, whether the change was related to radiation releases from the plant. A conclusion of this study was:

> For accident emissions, the authors failed to find definite effects of exposure on the cancer types and population subgroups thought to be most susceptible to radiation. No associations were seen for leukemia in adults or for childhood cancers as a group (reference 28).

Of particular interest to workers in the Naval Nuclear Propulsion Program are studies of groups occupationally exposed to radiation. A 1990 survey of radiation-worker populations in the U.S. showed there were about 350,000 workers under study (reference 26). For more than a decade, Naval Nuclear Propulsion Program personnel, including those at shipyards and in the Fleet, have been included among populations being studied. These studies are discussed below.

In 1978, Congress directed the National Institute for Occupational Safety and Health (NIOSH) to perform a study of workers at the Portsmouth Naval Shipyard in response to an article in the *Boston Globe* newspaper describing research by Dr. T. Najarian and Dr. T. Colton, assisted by the *Boston Globe* staff. The report alleged that Portsmouth Naval Shipyard workers who were occupationally exposed to low-level radiation suffered twice the expected rate of overall cancer deaths and five times the expected rate of leukemia deaths. Congress also chartered an independent oversight committee of nine national experts to oversee the performance of the study in order to ensure technical adequacy and independence of the results. The following is a NIOSH summary of the study and their results. This summary was prepared by NIOSH at the conclusion of their last study phase in February 1986.

> In December 1980, NIOSH researchers completed the first report on a detailed study of the mortality among employees of the shipyard. Included in the study were all those who had been employed at Portsmouth Naval Shipyard since January 1, 1952 (the earliest date that records existed that could identify former employees). In this report it was concluded that "Excesses of deaths due to malignant neoplasms and specifically due to neoplasms of the blood and blood-forming tissue, were not evident in civilian workers at Portsmouth Naval Shipyard. . . ." in contrast to the results of the original study conducted by the physician. Later, in an investigation to determine why the physician's study results differed so greatly from the

NIOSH study, a number of shortcomings in his original study were found that resulted in incorrect conclusions.

To make more certain that workers who had died from leukemia did not die because of radiation exposures received at the shipyard, a second study was conducted. That study compared the work and radiation histories of persons who died of leukemia, with persons who did not. In this analysis, again, no relationship was found between leukemia and radiation, although the NIOSH researchers were unable to rule out the possibility of other occupational exposures having a role.

In this current and third NIOSH paper, we investigated the role that radiation and other occupational exposures at the shipyard may have had in the development of lung cancer. This study is an outgrowth of an observation made in the 1980 NIOSH study referred to above. The observation was that persons with greater than 1 rem cumulative exposure to radiation had an increase in lung cancer.

In this report entitled, "Case Control Study of Lung Cancer in Civilian Employees at the Portsmouth Naval Shipyard," we compared the work and radiation histories of persons who died of lung cancer with persons who did not. We found that persons with radiation exposures in excess of 1 rem had an excess risk of dying of lung cancer, but the radiation was in all likelihood not the cause. This was due to the fact that persons with radiation exposure tended also to have exposure to asbestos (a known lung carcinogen) and to welding by-products (suspected to contain lung carcinogens).

Thus, the earlier reports of excess cancer rates among Portsmouth Naval Shipyard workers exposed to low-level radiation were not substantiated by NIOSH. The NIOSH studies were published in the scientific literature in references 29 through 32.

In 1991, researchers from Johns Hopkins University, Baltimore, Maryland, completed a more comprehensive epidemiological study of the health of workers at the six Navy shipyards and two private shipyards that serviced Navy nuclear-powered ships (reference 33). This independent study evaluated a population of 70,730 civilian workers over a period from 1957 (beginning with the first overhaul of the first nuclear-powered submarine, USS NAUTILUS) through 1981, to determine whether there was an excess risk of leukemia or other cancers associated with exposure to low levels of gamma radiation.

This study did not show any cancer risks linked to radiation exposure. Furthermore, the overall death rate among radiation-exposed shipyard workers was actually less than the death rate for the general U.S. population. It is well recognized that many worker populations have lower mortality rates than the general population, because the workers must be healthy to perform their work. This study shows that the radiation-exposed shipyard population falls into this category.

The death rate for cancer and leukemia among the radiation-exposed workers was slightly lower than that for non-radiation-exposed workers and that for the general U.S. population. However, an increased rate of mesothelioma, a type of respiratory system cancer linked to asbestos exposure, was found in both radiation-exposed and non-radiation-exposed shipyard workers, although the number of cases was small (reflecting the rarity of this disease in the general population). The researchers suspect that shipyard worker exposure to asbestos in the early years of the Program, when the hazards associated with asbestos were not so well understood as they are today, might account for this increase.

In conclusion, the Johns Hopkins study found no evidence to conclude that the health of people involved in work on U.S. nuclear-powered ships has been adversely affected by exposure to low levels of radiation incidental to this work. Additional studies are planned to investigate the observations and update the study with data beyond 1981.

In 1987, the Yale University School of Medicine completed a study (reference 34) sponsored by the U.S. Navy Bureau of Medicine and Surgery of the health of Navy personnel assigned to nuclear submarine duty between 1969 and 1981. The objective of the study, begun in 1979, was to determine whether the enclosed environment of submarines has had any impact on the health of these personnel. Although not strictly designed as a cancer study of a low-dose population, the study did examine cancer mortality as a function of radiation exposure. The study concluded that submarine duty has not adversely impacted the health of crewmembers. Furthermore, there was no correlation between cancer mortality and radiation exposure. These observations were based on comparison of death rates among the approximately 76,000 officers and enlisted submariners (all who served between 1969 and 1981) against an age-matched peer group. The results of this study were published in the Journal of Occupational Medicine (reference 35).

Table 7 below summarizes the Yale study results for enlisted submariners. The officer data show similar trends. (Note the SSBN population was larger than the fast-attack submarine [SSN] population, hence the larger number of expected cancer deaths. Also, SSBN & SSN is defined as service aboard both types of submarines.) As seen in Table 7, cancer deaths among both SSBN and SSN Sailors are less than cancer deaths among their age-matched peers in the civilian population.

TABLE 7

YALE STUDY RESULTS

Enlisted Submariners (76,160)	Cancer Deaths Observed	Cancer Deaths Expected
SSBN	55	61
SSN	18	36
SSBN & SSN	4	12
Total	77	109

Numerical Estimates of Risk from Radiation

One of the major aims of the studies of exposed populations as discussed above is to develop numerical estimates of the risk of radiation exposure. These risk estimates are useful in addressing the question of how hazardous radiation exposure is, evaluating and setting radiation protection standards, and helping resolve claims for compensation by exposed individuals.

The development of numerical risk estimates has many uncertainties. As discussed above, excess cancers attributed to radiation exposure can only be observed in populations exposed to high doses and high-dose rates. However, the risk estimates are needed for use in evaluating exposures from low doses and low-dose rates. Therefore, the risk estimates derived from the high-dose studies must be extrapolated to low doses. This extrapolation introduces a major uncertainty. The shape of the curve used to perform this extrapolation becomes a matter of hypothesis (that is,

assumption) rather than observation. The inability to observe the shape of this extrapolated curve is a major source of controversy over the appropriate risk estimate.

Scientific committees, such as the National Academy of Science (reference 17), the United Nations Scientific Committee on the Effects of Atomic Radiation (reference 19), and the National Council on Radiation Protection and Measurements (reference 12) all conclude that accumulation of dose over weeks, or months, as opposed to in a single dose, is expected to reduce the risk. A dose rate effectiveness factor (DREF) is applied as a divisor to the risk estimates at high doses to permit extrapolation to low doses. The National Academy of Sciences (reference 17) suggested that a range of DREFs between 2 and 10 may be applicable and reported a best estimate of 4, based on studies of laboratory animals. The United Nations Scientific Committee on the Effects of Atomic Radiation (reference 19) suggested that a DREF of 2 or 3 would be reasonable based on available data. However, despite these conclusions by the scientific committees, some critics argue that the risk actually increases at low doses, while others argue that cancer induction is a threshold effect and the risk is zero below the threshold dose. As stated at the beginning of this section, the Naval Nuclear Propulsion Program has always conservatively assumed that radiation exposure, no matter how small, may involve some risk.

In 1972, both the United Nations Scientific Committee on the Effects of Atomic Radiation and the National Academy of Sciences-National Research Council Advisory Committee on the Biological Effects of Ionizing Radiation issued reports (references 36 and 37) that estimated numerical risks for specific types of cancer from radiation exposure to human beings. Since then, international and national scientific committees have been periodically re-evaluating and revising these numerical estimates based on the latest data. The most recent risk estimates are from the same two committees and are contained in their 1990 and 2000 reports, respectively (references 17 and 19). Both committees re-evaluated risk estimates based on the use of new models for projecting the risk, revised dose estimates for survivors of the Hiroshima and Nagasaki atomic bombs, and additional data on the cancer experience both by atomic bomb survivors and by persons exposed to radiation for medical purposes. A risk estimate for radiation-induced cancer derived from the most recent analyses, references 17 and 19, can be briefly summarized as follows:

> In a group of 10,000 workers in the U.S., a total of about 2,000 (20 percent) will normally die of cancer. If each of the 10,000 received over his or her career an additional 1 rem, then an estimated 4 additional cancer deaths (0.04 percent) might occur. Therefore, the average worker's lifetime risk of cancer has been increased nominally from 20 percent to 20.04 percent.

The above risk estimate was extrapolated from estimates applicable to high doses and dose rates using a DREF of about 2. This estimate may overstate the true lifetime risk at low doses and dose rates, because a DREF of 2 is at the low end of probable DREF values. The National Academy of Sciences (reference 17), in assessing the various sources of uncertainty, concluded that the true lifetime risk may be contained within an interval from zero to about six. The Academy points out that the lower limit of uncertainty extends to zero risk because "the possibility that there may be no risks from exposure comparable to external natural background radiation cannot be ruled out."

These statistics can be used to develop a risk estimate for personnel exposed to radiation associated with naval nuclear propulsion plants. As stated previously, the average lifetime accumulated exposure is approximately 1.3 rem for all shipyard personnel and approximately 0.73 rem for all Fleet personnel. Therefore, based on a Program-wide average of about 1 rem and the risk estimate presented above, the average worker's lifetime cancer risk in the Naval Nuclear Propulsion Program may be increased a very small amount, from 20 percent to 20.04 percent.

Risk Comparisons

Table 8 compares calculated risks from occupational exposure in the Naval Nuclear Propulsion Program to other occupational risks. This allows us to evaluate the relative hazard of this risk versus risks normally accepted in the workplace. It should be kept in mind that the radiation risk is calculated based on risk estimates, whereas the other occupational risks are based on actual death statistics for the occupation.

TABLE 8

LIFETIME OCCUPATIONAL RISKS

Occupation (reference 12)	Lifetime Risk[7] Percent
Agriculture	2.1
Mining, Quarrying	2.0
Construction	1.5
Transportation and Public Utilities	1.0
All Industries Average	0.4
Government	0.4
Services	0.2
Manufacturing	0.2
Trade	0.2
Radiation exposure associated with naval nuclear propulsion plants (risk estimate)	0.04

Further perspective on the lifetime risk from radiation exposure in the Naval Nuclear Propulsion Program may be gained by comparison to other everyday risks as shown in Table 9.

TABLE 9

SOME COMMONPLACE LIFETIME RISKS

Lifetime Risk[8] Risk (references 38 and 39)	Percent
Smoking	9
Accidents (all)	2.6
Motor Vehicle Accidents	1.2
Falls	0.34
Accidental Poisoning	0.29
Suffocation	0.13
Drowning	0.11
Fires	0.10
Public Transportation	0.05
Radiation exposure associated with naval nuclear propulsion plants (risk estimate)	0.04

7. Assumes a working lifetime of 47 years (age 18 to 65).
8. Smoking and Motor Vehicle Accidents assume the population is at risk from age 18 to 76.5 (58.5 years). Other risks assume the population is at risk for a lifetime (76.5 years).

Low-Level Radiation Controversy

A very effective way to cause undue concern about low-level radiation exposure is to claim that no one knows what the effects are. This has been repeated so often that it has almost become an article of faith that no one knows the effects of low-level radiation on human beings. The critics can make this statement because, as discussed above, human studies of low-level radiation exposure cannot be conclusive as to whether or not an effect exists in the exposed groups, because of the extremely low incidence of an effect. Therefore, assumptions are needed regarding extrapolation from high-dose groups. The reason low-dose studies cannot be conclusive is that the risk, if it exists at these low levels, is too small to be seen in the presence of all the other risks of life.

The fact that a controversy exists is evidence that the radiation risk is small.

In summary, the effect of radiation exposures at occupational levels is extremely small. There are physical limits to how far scientists can go to ascertain precisely the size of this risk, but it is known to be small. Instead of proclaiming how little is known about low-level radiation, it is more appropriate to emphasize how much is known about the small actual effects.

Conclusions on the Effects of Radiation on Personnel

This perspective provides a better position to answer the question, "Is radiation safe?" If safe means zero effect, then the conclusion would have to be that radiation may be unsafe. But to be consistent, background radiation and medical radiation would also have to be considered unsafe. Or more simply, being alive is unsafe.

"Safe" is a relative term. Comparisons are necessary for actual meaning. For a worker, safe means the risk is small compared to other risks accepted in normal work activities. Aside from work, safe means the risk is small compared to the risks routinely accepted in life.

Each recommendation on limits for radiation exposure from the scientific and advisory organizations referenced herein has emphasized the need to minimize radiation exposure. Thus, the Naval Nuclear Propulsion Program is committed to keeping radiation exposure to personnel as low as reasonably achievable. Scientific and advisory organizations have not agreed on a radiation exposure level below which there is no effect. Similarly, it is difficult to find a single human activity for which the risk can be confidently stated as zero. However, the above summaries show that the risk from radiation exposure associated with naval nuclear propulsion plants is low compared to the risks normally accepted in industrial work and in daily life outside of work.

CLAIMS FOR RADIATION INJURY TO PERSONNEL

Personnel who consider they have or might have had occupational injury may file claims. Naval shipyard personnel are employees of the U.S. Government and therefore file claims with the U.S. Department of Labor's Office of Workers' Compensation. Shipyards hold no hearings on injury claims. They are not handled in an adversary procedure. The claim does not even have to be filed through the shipyard. The shipyard is not permitted to appeal a decision, but the employee may appeal. The primary consideration in the Federal laws and procedures set up for injury compensation is to take care of the Federal employee. The program to compensate Federal employees is well publicized.

In private shipyards injury compensation claims are handled under the Longshore and Harbor Workers' Compensation Act. The claim may be handled through the shipyard's insurance carrier or by a U.S. Department of Labor claims examiner. Either the employee or the employer may appeal.

Claims for military personnel concerning prior duty are handled through the Veterans Administration.

In any case, the Naval Nuclear Propulsion Program would support any claim for radiation injury where it could be technically and scientifically shown that the injury was more likely than not caused by the individual's occupational radiation exposure from the Program.

There have been a total of 382 claims filed for injury from radiation associated with naval nuclear propulsion plants. Of these, 148 originated from employees of the naval shipyards, 67 from private shipyards, and 167 from Navy personnel. These claims are summarized in Table 10. As shown in Table 10, approximately two-fifths of the claims have been filed for injuries other than cancer or leukemia. Approximately four-fifths of the claims filed for cancer or leukemia involved workers with <u>lifetime radiation exposures less than 5 rem</u>, which is the exposure a nuclear worker is permitted to receive in <u>1 year</u> by Federal regulations.

TABLE 10

CLAIMS FOR RADIATION INJURY TO PERSONNEL

Claims Claimed	Injury Filed	Claims Awarded	Claims Claims or Deferred	Denied Active
Leukemia	55	4	49	2
Cancer Other Than Leukemia	189	2	181	6
Other	138	5	132	1
TOTAL	382	11	362	9

Naval shipyard personnel workers' compensation claims are generally decided upon by the Office of Workers' Compensation within 1-2 years of filing. The Longshore and Harbor Workers' Compensation Act, however, will not require a decision on a case subsequent to filing unless it is actively pursued by the claimant. For cases that are not actively pursued, the claim may lie dormant for many years theoretically to be pursued at

a later date, whereupon a decision will be made. For the purpose of Table 10, claims which have had no activity in the last 5 years are listed as deferred.

Eleven claims have been awarded for which radiation was an alleged causal agent: four for leukemia in 1968, 1979, 1991, and 1999; four for cataracts of the eyes in 1971, 1974, 1977, and 1982; one for leukocytosis in 1969; one for bile duct/pancreatic cancer in 1980; and one for metastatic carcinoma of undetermined origin in 1998. The Office of Workers' Compensation awarded three claims, and the VA awarded eight claims. For VA claims, other considerations (such as whether the injury is reasonably considered to have occurred while the claimant was in the Armed Forces and other causal factors) are used when awarding claims. The Navy considers all 11 of these awards were unjustified on the basis of radiation exposure, as follows:

- One leukemia case had a lifetime occupational exposure of 5.38 rem. The claimant had also received hundreds of rem in medical radiation exposure for adenoids. If radiation were to be selected as the cause of this leukemia, then the occupational exposure could not have been more than a tiny part of the total radiation exposure.

- The second leukemia case had a lifetime occupational exposure of 1.00 rem. This amount of radiation exposure is small and is less than 10 percent of the amount of exposure the claimant will receive during his life from natural background and medical radiation.

- The third leukemia case had a lifetime occupational exposure of 4.20 rem (2.98 rem of which was received while in the U.S. Navy). This amount of radiation exposure is less than 10 percent of the exposure the claimant was allowed under Federal limits for the 12 years he was occupationally exposed to ionizing radiation.

- The fourth leukemia case had a lifetime occupational exposure of 1.054 rem. Again, this amount of radiation exposure is small and is less than 10 percent of the amount of exposure the claimant will receive during his life from natural background and medical radiation.

- Two of the cataract cases had lifetime radiation exposures of about 3 rem, one case had less than 1 rem, and one case had 0.02 rem. Of these cases, even the highest exposure, 3 rem, is hundreds of times smaller than needed to produce cataracts in the eyes (reference 17).

- The leukocytosis (elevated white blood cell count) case had a lifetime occupational exposure of 15.5 rem, which was received over an 8-year period. This case was evaluated by the medical research center of a national laboratory, which concluded that the cause of the leukocytosis was unknown. In addition, leukocytosis has not been shown to be associated with low-level occupational radiation exposure.

- The bile duct and pancreatic cancer case was awarded for a lifetime occupational exposure of 2.37 rem. This amount of radiation is less than the quarterly limit of 3 rem and the annual limit of 5 rem. Further, this person received about four times the amount of his occupational exposure from natural background and medical exposures over his lifetime.

- The metastatic carcinoma case was awarded for a lifetime occupational exposure of 2.834 rem. This amount of radiation is less than the quarterly limit of 3 rem and the annual limit of 5 rem. Further, this person received

over five times the amount of his occupational exposure from natural background and medical exposure over his lifetime.

In addition to the above claims, six suits have been filed in court alleging injury from radiation. One suit involved leukemia; three involved other cancers; and the two others did not involve a cancer. Five of these suits were dismissed and one was settled.

AUDITS AND REVIEWS

Checks and cross-checks, audits, and inspections of numerous kinds have been shown to be essential in maintaining high standards of radiological controls. First, all workers are specially trained in radiological controls as it relates to their own job. Second, written procedures exist which require verbatim compliance. Third, radiological controls technicians and their supervisors oversee radioactive work. Fourth, personnel independent of radiological controls technicians are responsible for personnel radiation exposure records.

Fifth, a strong independent audit program is required covering all radiological controls requirements. In all shipyards this radiological audit group is independent of the radiological controls organization; the audit group's findings are reported regularly to senior shipyard management, including the shipyard commander or shipyard president. This group performs continuing surveillance of radioactive work. It conducts indepth audits of specific areas of radiological controls. This group checks all radiological controls requirements at least annually.

Sixth, the U.S. Department of Energy assigns to each shipyard a representative who reports to the Director, Naval Nuclear Propulsion, at Headquarters. One assistant to this representative is assigned full-time to audit and review radiological controls, both in nuclear-powered ships and in the shipyard. Seventh, Naval Nuclear Propulsion Program Headquarters personnel conduct periodic inspections of radiological controls in each shipyard. Similarly, there are multiple levels of audits and inspections for the other naval shore facilities, tenders, and nuclear-powered ships.

In addition, various aspects of the Naval Nuclear Propulsion Program have been reviewed by other Government agencies. For example, the National Institute for Occupational Safety and Health conducted an evaluation of the radiological controls program at Portsmouth Naval Shipyard in conjunction with its mortality study at the shipyard (discussed earlier in this report). NIOSH published the results of its evaluation in a report (reference 40) in April 1983, which stated the following conclusions (quoted verbatim):

- The employee dose data provided NIOSH by Portsmouth Naval Shipyard is complete and provides a reasonable estimate of the individual worker's dose.
- The Portsmouth Naval Shipyard personnel dosimetry program provides accurate internal and external dose data.
- The external and internal doses received by Portsmouth Naval Shipyard personnel are low compared to present occupational exposure guidelines.
- The probability of unreported accidents/ incidents or undocumented exposures is extremely small.
- The radiological controls employed are adequate to protect the worker from internal and external hazards.
- The impact of the nuclear work at Portsmouth Naval Shipyard to the surrounding environment is minimal or negligible.
- Nuclear operations at Portsmouth Naval Shipyard are not contributing a significant radiation dose to the general public.

Another example of an independent governmental review of the Naval Nuclear Propulsion Program was the General Accounting Office (GAO) 14-month indepth review of various aspects of the Program's Department of Energy facilities. These Department of Energy facilities operate to the same radiological control requirements as other Naval Nuclear Propulsion Program (Naval Reactors) facilities. In August 1991 (reference 41), the GAO published the following conclusions:

- We believe Naval Reactors Laboratories are accurately measuring, recording, and reporting radiation exposures.
- Naval Reactors reported exposures show that exposures have been minimal and overall are lower than commercial nuclear facilities and other DOE facilities.

ABNORMAL OCCURRENCES

It is a fact of human nature that people make mistakes. The key to a good radiological controls program is to find the mistakes while they are small and prevent the combinations of mistakes that lead to more serious consequences. The preceding section on inspections supports the conclusion that the Naval Nuclear Propulsion Program gives more attention to errors and their prevention than to any other single subject. Requiring constant focus on improving performance of radiological work has proven effective in reducing errors.

In addition, radiological controls technicians are authorized and required to stop anyone performing work in a manner that could lead to radiological deficiencies. One definition of "deficiency" is a failure to follow a written procedure verbatim. However, the broadest interpretation of the term "deficiency" is used in the Navy's radiological controls program. Anything involved with radiation or radioactivity that could have been done better is also considered a radiological deficiency. All radiological deficiencies receive management attention.

There is a higher level of deficiency that is defined as a radiological incident. Incidents receive further management review, including evaluation by senior personnel at Headquarters and review by the Director, Naval Nuclear Propulsion. Improvement programs over the years have constantly aimed at reducing the numbers of radiological incidents. As improvements occurred, the definition of what constituted an incident was changed to define smaller and smaller deficiencies as incidents. These changes were necessary so that the incident reporting system would continue to play a key role in upgrading radiological controls. As a result, it is not practicable to measure performance over time merely by counting numbers of radiological incidents or deficiencies.

The Department of Energy and its predecessors have used a separate reporting system that has been nearly constant over time and therefore can be used as a basis for comparison. This system defines a Type A radiation exposure occurrence as an event that causes an individual's external radiation exposure to equal or exceed 25 rem (reference 42). The Nuclear Regulatory Commission uses similar criteria to define an abnormal occurrence; abnormal occurrences are included in the NRC's quarterly report to Congress. The Navy regularly evaluates radiological events using these criteria for comparison.

Since the beginning of operations in the Naval Nuclear Propulsion Program, there has not been a single radiation incident that met the criteria of a Type A or abnormal occurrence.

The policy of the Navy is to provide for close cooperation and effective communication with State radiological officials involving occurrences that might cause concern because of radiological effects associated with the ships or shore facilities. The Navy has reviewed radiological matters with State radiological officials in the States where naval nuclear-powered ships are based or overhauled. Although there has never been an abnormal occurrence that has resulted in radiological effects to the public outside these facilities or that resulted in radiological injury to residents of the States working inside these facilities, States were notified when inquiries showed public interest in the possibility such events had occurred.

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OCCUPATIONAL RADIATION EXPOSURE FROM NAVAL REACTORS' DEPARTMENT OF ENERGY FACILITIES

NAVAL NUCLEAR PROPULSION PROGRAM
OFFICE OF NAVAL REACTORS
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OCCUPATIONAL RADIATION EXPOSURE FROM NAVAL REACTORS' DEPARTMENT OF ENERGY FACILITIES

2002

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

SUMMARY

The Naval Nuclear Propulsion Program is a joint Department of Energy (DOE)/ Department of the Navy Program with central control by a single headquarters organization. Within the Department of Energy, the organization is designated as the Office of Naval Reactors and it operates two DOE laboratories, one DOE site with two operating and two inactive prototype naval nuclear propulsion plants, one DOE site which operates the Expended Core Facility (for examination and dispositioning of naval fuel and irradiation tests) and has three inactive prototype nuclear propulsion plants, and two nuclear component engineering and procurement organizations. Table 1 shows the facilities that have conducted radioactive work associated with the Naval Reactors Program and the date when such work began. Naval Reactors' Department of Energy facilities provide research and development, engineering, training, and supply support for the Navy's 73 nuclear-powered submarines and 9 nuclear-powered aircraft carriers that were in operation at the end of 2002.

Radiation exposures to personnel monitored for radiation associated with Naval Reactors' Department of Energy facilities are summarized in this report. Also included in this report is radiation exposure information from the Shippingport Atomic Power Station, near Pittsburgh, Pennsylvania. Shippingport was developed by the Naval Reactors Program, in conjunction with Duquesne Light Company, as the world's first full-scale atomic power plant solely for the production of electricity, and began operation in 1957. Starting in 1974, the light water breeder reactor (LWBR) core was installed at Shippingport; this was the first reactor to prove that fuel breeding was possible in a water-cooled plant. Shippingport was shut down in 1982 and, following defueling, turned over to another office of the Department of Energy for dismantlement in 1984. Dismantlement was completed in 1989, removing all radioactive components and returning the site to unrestricted use.

Figure 1 shows that the total radiation exposure in 2002 is less than 4 percent the amount in the peak year of 1975 and that the number of personnel monitored has decreased by almost 60 percent since 1975. The large increase in radiation exposure in 1975 was due to refueling operations at one of the prototype naval nuclear propulsion plants and to fabrication and installation of the LWBR core at Shippingport. LWBR was unique in this sense because the core was manufactured at one of the Naval Reactors Program laboratories (other cores were manufactured by subcontractors) and the fissile material was uranium-233 rather than uranium-235. Total rem in this figure is the sum of the annual exposure of each person monitored for radiation.

No personnel at Naval Reactors' Department of Energy facilities have ever exceeded the applicable Federal annual exposure limit. In 1958 the Federal annual exposure limit was 15 rem per year. The Federal limit was changed in 1960 to 3 rem per quarter and 5 rem accumulated dose for each year beyond the age of 18. Since 1973 no one has exceeded the Federal limit of 3 rem per quarter established in 1960; prior to 1973, 14 people at Naval Reactors' Department of Energy facilities exceeded this level. Of these individuals, 13 received exposures less than 1 rem above the limit, and the remaining individual received 8.1 rem in a quarter. No one has exceeded the Program's self-imposed limit of 5 rem per year since this limit was established in 1967. The Federal limit was changed in 1994 to adopt the 5 rem per year limit already in use by Naval Reactors in lieu of the accumulated exposure limit.

The average occupational exposure of each person monitored at Naval Reactors' Department of Energy facilities since 1958 is 0.114 rem per year. The lifetime accumulated exposure from radiation associated with Naval Reactors' Department of Energy facilities to date for all personnel monitored has averaged less than 1 rem per person.

According to the standard methods for estimating risk, the risk to the group of personnel occupationally exposed to radiation associated with the Naval Reactors Program is less than the risk these same personnel have from exposure to natural background radiation. This risk is small compared to the risks accepted in normal industrial activities, and it is small compared to the risks regularly accepted in daily life outside of work.

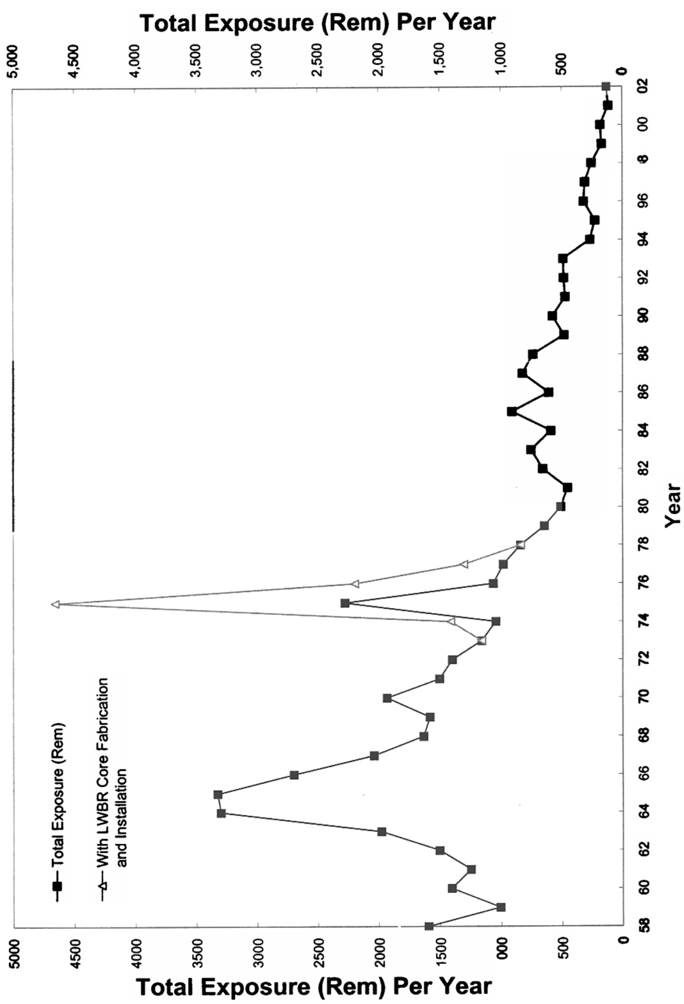
TABLE 1

INITIAL LABORATORY AND PROTOTYPE OPERATIONS

Location	Year Initial Operations Began Involving Radioactive Work
Bettis Atomic Power Laboratory West Mifflin, Pennsylvania	1950
Knolls Atomic Power Laboratory Schenectady, New York	1950[1]
Naval Reactors Facility Idaho Falls, Idaho	1953
Kenneth A. Kesselring Site Ballston Spa, New York	1955
Windsor Site Operation Windsor, Connecticut	1959[2]
Shippingport Atomic Power Station Beaver Falls, Pennsylvania	1957[3]
Bechtel Plant Machinery, Incorporated – Pittsburgh Monroeville, Pennsylvania	N/A[4]
Bechtel Plant Machinery ,Incorporated – Schenectady Schenectady, New York	N/A[4]

1. Naval Reactors Program work began at Knolls Atomic Power Laboratory in 1950. Non-Naval Reactors Program isotope separations process research work was performed at Knolls on behalf of the Atomic Energy Commission from 1947 through 1953.
2. In 1993, training operations at the Windsor Site Operation prototype stopped and the dismantlement of the prototype and support facilities began. Dismantlement was completed in 2000.
3. Shippingport Atomic Power Station was shut down in 1982 and turned over to another office of the Department of Energy for dismantlement in 1984. Dismantlement was completed in 1989.
4. No work involving radioactive materials is performed by Bechtel Plant Machinery, Incorporated. The small amount of radiation exposure received by personnel at these facilities is the result of visits to other Program facilities. Bechtel Plant Machinery, Incorporated – Schenectady, formerly known as Bechtel Machinery Apparatus Operation, was previously operated by Westinghouse and General Electric. Bechtel Plant Machinery, Incorporated – Pittsburgh, formerly known as Bechtel Plant Apparatus Division, was previously operated by Westinghouse.

FIGURE 1
TOTAL RADIATION EXPOSURE RECEIVED BY PERSONNEL AT NAVAL REACTORS' DEPARTMENT OF ENERGY FACILITIES 1958 - 2002



EXTERNAL RADIATION EXPOSURE

Policy and Limits

The policy of the Naval Reactors Program is to reduce exposure to personnel from ionizing radiation associated with Naval Reactors' Department of Energy facilities to a level as low as reasonably achievable.

Prior to 1960, the Federal radiation exposure limit used in the U.S. for whole body radiation was 15 rem[1] per year. From 1960 to 1994, the Federal radiation exposure limits used in the U.S. for whole body radiation exposure were 3 rem per quarter year and 5 rem accumulated dose for each year beyond age 18. These limits were recommended in 1958 by the U.S. National Committee ("Committee" was changed to "Council" when the organization was chartered by the U.S. Congress in 1964) on Radiation Protection and Measurements (reference 1)[2] and by the International Commission on Radiological Protection (reference 2). They were adopted by the U.S. Atomic Energy Commission (AEC) and applied both within the AEC and to licensees in 1960 (reference 3). On May 13, 1960, President Eisenhower approved the U.S. Federal Radiation Council recommendation that these limits be used as guidance for Federal agencies (reference 4). A key part of each of these standards has been emphasis on minimizing radiation exposure to personnel.

In 1965, the International Commission on Radiological Protection (reference 5) reiterated the quarterly and accumulated limits cited above but suggested that exceeding 5 rem in 1 year should be infrequent. Although none of the other organizations referred to above changed their recommendations accordingly, the Naval Reactors Program adopted 5 rem per year as a rigorous limit, effective in 1967.

In 1971, the National Council on Radiation Protection and Measurements (reference 6) recommended that 5 rem be adopted as the annual limit under most conditions. In 1974 the Atomic Energy Commission (now the Department of Energy) (reference 7) established 5 rem as its annual limit. In 1977, the International Commission on Radiological Protection (reference 8) deleted the accumulated limit and recommended 5 rem as the annual limit. In 1979, the Nuclear Regulatory Commission (NRC) issued a proposed change to the Code of Federal Regulations, Title 10, Part 20, to require its licensees to use 5 rem as an annual limit. On January 20, 1987, revised guidance for Federal agencies was approved by President Reagan that eliminated the accumulated dose limit discussed above and established a 5 rem per year limit for occupational radiation exposure (reference 9). The Nuclear Regulatory Commission revised the Code of Federal Regulations, Title 10, Part 20, making the 5 rem annual limit effective on January 1, 1994.

The Naval Reactors Program radiation exposure limits since 1967 have been:

3 rem per quarter
5 rem per year

Special higher limits are in effect, such as those for hands and feet; however, there have been few cases where these limits have been more restrictive than the whole body radiation exposure limits. Therefore, the radiation exposures discussed in this report are nearly all from whole body radiation. Controls are also in effect to minimize any occupational radiation exposure to the unborn child of a pregnant worker.

Each Naval Reactors' Department of Energy facility is required to have an active program to reduce radiation exposure to the minimum practicable.

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1. 1 rem = 0.01 Sievert
2. References are listed on pages 44 through 46.

Sources of Radiation at Prototypes

One of the Naval Reactors Department of Energy sites operates two prototype naval nuclear propulsion plants (Kesselring Site Operation, Ballston Spa, New York). This facility is engaged in testing nuclear propulsion plants for the U.S. Navy and training U.S. Navy propulsion plant operators. The other site (the Naval Reactors Facility on the Idaho National Engineering and Environmental Laboratory (INEEL) site near Idaho Falls, Idaho) has prototype plants that have been inactivated. The Naval Reactors Facility also houses the Expended Core Facility. Personnel at the Expended Core Facility receive, examine, prepare spent naval fuel modules for transfer to the Idaho Nuclear Technology Engineering Center, and prepare spent fuel for long term storage in a geological repository. The Expended Core Facility also examines the Naval Reactors Program's irradiated material samples from the INEEL's Test Reactor Area.

The radiation exposures at the prototype sites originate primarily from pressurized water reactors. Water circulates through a closed piping system to transfer heat from the reactor core to a secondary steam system isolated from the reactor cooling water. Trace amounts of corrosion and wear products are carried by reactor coolant from reactor plant metal surfaces. Some of these corrosion and wear products are deposited on the reactor core and become radioactive from exposure to neutrons. Reactor coolant carries some of these radioactive products through the piping systems where a portion of the radioactivity is removed by a purification system. Most of the remaining radionuclides transported from the reactor core deposit in the piping systems.

The reactor core is installed in a heavy-walled pressure vessel within a primary shield. This shield limits radiation exposure from the gamma and neutron radiation produced when the reactor is at power. Reactor plant piping systems are installed primarily inside a reactor compartment that is surrounded by a secondary shield. Access to the reactor compartment is permitted only after the reactor is shut down. Most radiation exposure to personnel comes from inspection, maintenance, and repair inside the reactor compartment. The major source of this radiation is cobalt-60 deposited inside the piping systems. Cobalt-60 emits two high-energy gamma rays and a low-energy beta particle for every radioactive decay. Its half-life is 5.3 years.

Neutrons that are produced when reactor fuel fissions are shielded from occupied areas by primary and secondary shields. Radiation exposure to personnel from these neutrons during reactor operation is much less than from gamma radiation. After reactor shutdown, when maintenance and other support work is done, no neutron exposure is detectable. As a result, the radiation exposures at prototypes are primarily from gamma radiation.

Radiation exposure at the Expended Core Facility is also due to gamma radiation emitted by irradiated reactor fuel and structural components that were inside the reactor vessel during operation and became radioactive by exposure to neutrons. Work on these components is performed remotely in either specially designed shielded cells or in deep water pits where many feet of water shield personnel.

Exposures listed in this report for prototype personnel include Department of Energy employees and contractors as well as exposure to Navy staff and students involved in training at the sites.

Sources of Radiation at Laboratories

The two Naval Reactors' laboratories (Bettis Atomic Power Laboratory, near Pittsburgh, Pennsylvania and Knolls Atomic Power Laboratory, near Schenectady, New York) conduct research and development work on improved nuclear propulsion plants for U.S. Navy warships. At the laboratories, external radiation exposure is attributable to examination and analysis of irradiated materials and fuel. Gamma radiation is the significant contributor to dose. Although alpha and beta radiation are present, they are

generally well shielded. Neutron radiation contributes very little to doses at the laboratories.

Irradiated materials include mixed fission products and activation products. The activation products are identical to those discussed in the preceding section. Fission products are the radioactive species produced by the fissioning of nuclear fuel. Fission products generally emit both beta and gamma radiation and have half-lives ranging from hours to many years. In cases where these materials emit significant levels of radiation, the analyses and examinations are performed remotely using special tooling in shielded cells similar to those used at the Expended Core Facility. With regard to fuel, the preparation of fuel specimens involves the handling of unirradiated uranium. The dose rates from these materials are generally low. Irradiated fuel specimens are handled in the shielded cells.

Radiation exposures for the Shippingport Atomic Power Station are also included under the heading for laboratory personnel. The sources of radiation exposure at Shippingport were similar to those at the prototype sites. From 1974 to 1977, the Bettis Atomic Power Laboratory fabricated and installed the Light Water Breeder Reactor (LWBR) core for Shippingport. The fissile fuel for this core was uranium-233 and the fertile fuel was thorium-232. Enriched uranium-233 contains a significantly higher level of uranium-232 than enriched uranium-235. The radioactive decay chain of uranium-232, in turn, includes thallium-208, which emits a high-energy gamma ray with each decay; accordingly, the radiation exposure of personnel fabricating the LWBR core was much higher than for fabrication of traditional uranium-235 cores. In addition to fabrication, there was also significant radiation exposure due to LWBR installation inside the Shippingport power plant.

Also included under the laboratory heading is the small amount of exposure to personnel assigned to the two Naval Reactors' Department of Energy nuclear component engineering and procurement organizations (Bechtel Plant Machinery, Incorporated – Pittsburgh, near Monroeville, Pennsylvania, and Bechtel Plant Machinery, Incorporated - Schenectady, near Schenectady, New York). In 2001, personnel at these facilities received a combined total of about 2.8 rem of occupational radiation exposure. Since no radioactive material is handled at these facilities, this exposure is the result of visits to other Naval Reactors Program activities where nuclear-powered ships are built and maintained.

Control of Radiation

Reactor plant shielding is designed to minimize radiation exposure to personnel. Shield design criteria establishing radiation levels in various parts of each prototype are personally approved by the Director, Naval Nuclear Propulsion. The Director, Naval Nuclear Propulsion, also personally approved the shield design criteria for the Shippingport Atomic Power Station.

Prototype design is also controlled to keep locations such as duty stations, where personnel need to spend time, as far as practicable away from the reactor compartment shield. In addition, radiation outside propulsion plant spaces during reactor plant operation is not generally any greater than natural background radiation.

Laboratories, prototype sites, and the Expended Core Facility are designed so that radioactive material outside of reactor plants is handled only in specially designed and shielded facilities. Naval Reactors' Department of Energy facilities minimize the number of places where radioactive material is allowed. Stringent controls are in place during the movement of all radioactive material. A radioactive material accountability system is used to ensure that no radioactive material is lost or misplaced in a location where personnel could unknowingly be exposed. Regular inventories are required for every item in the radioactive material accountability system. Radioactive material is tagged with yellow and magenta tags bearing the standard radiation symbol and the measured

radiation level. Radioactive material is required to be placed in yellow plastic, and the use of yellow plastic is reserved solely for radioactive material. All personnel assigned to Naval Reactors' Department of Energy facilities are trained to recognize that yellow plastic identifies radioactive material and to initiate immediate action if radioactive material is discovered out of place.

Access to radiation areas is controlled by posted signs and barriers. Personnel are trained in the access requirements, including the requirement to wear dosimetry devices to enter these areas. Dosimetry devices are also posted near the boundaries of these areas to verify that personnel outside these areas do not require monitoring. Frequent radiation surveys are required using instruments that are checked before use and calibrated regularly. Areas where radiation levels are greater than 0.1 rem per hour are called "high radiation areas" and are locked or guarded. Compliance with radiological controls requirements is checked frequently by radiological controls personnel, as well as by other personnel not affiliated with the radiological controls organization.

Dosimetry

Thermoluminescent dosimeters (TLDs) are dosimetry devices worn by personnel to measure their exposure to gamma, neutron, and beta radiation. Prior to 1975, film badges were used as described below. The TLDs used at the prototypes contain two chips of calcium fluoride with added manganese. The TLDs used at the laboratories contain four chips of lithium fluoride. It is characteristic of thermoluminescent material that radiation causes internal changes that make the material, when subsequently heated, give off an amount of light directly proportional to the radiation dose.

Since the types of radiation to which personnel are exposed are different at the laboratories than at the prototypes and the Expended Core Facility, the design of the dosimeters is also different. At the prototypes and the Expended Core Facility, because the source of radiation exposure is high-energy gamma radiation, calcium fluoride TLDs are used. At the laboratories, high- and low-energy gamma radiation and beta radiation are present; therefore, lithium fluoride TLDs are used. Lithium fluoride TLDs were worn in addition to calcium fluoride TLDs at the Expended Core Facility from 1985 until 1998, when a review of monitoring data identified that the low-energy gamma and beta radiation doses were negligible compared to doses requiring monitoring by Federal standards; therefore, monitoring with lithium fluoride TLDs was determined to be no longer necessary for routine work. Shippingport used dosimeters similar to the ones used at the prototypes. At all facilities, separate TLDs are used for the few applications where neutron monitoring is required.

The calcium fluoride TLDs used at the prototypes and the Expended Core Facility are designed such that the two calcium fluoride chips are in contact with a metallic heating strip with heater wires extending through the ends of a surrounding glass envelope. The glass bulb is protected by a plastic case designed to permit the proper response to gamma radiation of various energies. The lithium fluoride TLDs used at the laboratories are designed such that the four lithium fluoride chips are encapsulated in teflon and mounted into pre-drilled holes in an aluminum card.

The calcium fluoride TLDs are processed, that is read, manually. A trained operator removes the glass bulb from the plastic case and places it in a TLD reader, bringing the metal heater wires into contact with an electrical circuit. An electronically controlled device heats the calcium fluoride chips to several hundred degrees Celsius in a timed cycle, and the intensity of light emitted is measured and converted to a digital readout in units of rem. The heating cycle also anneals the calcium fluoride chips so that the dosimeter is zeroed and ready for subsequent use. The entire cycle of reading a TLD described here takes about 30 seconds.

The processing of the laboratories' lithium fluoride TLDs is performed automatically: the operator can load as many as 1,400 lithium fluoride cards into the reader, and the TLD

reader automatically reads one TLD card at a time. To read the radiation exposure from the lithium fluoride TLDs, the operator removes the aluminum cards from the plastic cases and places them into cartridges that are loaded into the microprocessor-controlled TLD reader. To start the read process, one TLD card is automatically removed from the cartridge and positioned into the read position where the bar code identification number is read. The four chips are then simultaneously heated to several hundred degrees Celsius using four precisely temperature-controlled streams of hot nitrogen gas. During the heating of the TLDs, the lithium fluoride TLDs (like the calcium fluoride TLDs) give off light in proportion to the radiation they received. The light is converted to a graphical and digital readout, as well as digitally stored on a computer hard disk. This heating cycle also anneals the TLD chips so that the dosimeter is zeroed and ready for subsequent use. After readout, the TLD is then automatically moved to a removal cartridge. The entire read cycle for one card takes, on the average, 30 seconds. After processing, the computer converts the light output to dose in units of rem.

The rapid readout of the calcium fluoride and lithium fluoride TLDs was one reason for changing from film badges to TLDs. Processing film badges was a time-consuming chemical process; TLDs permit more frequent measurement of a worker's radiation exposure than film badges did. TLDs are processed at least quarterly, and for those individuals who are expected to receive higher exposures, at least monthly. For those who enter a reactor compartment, the TLDs are processed daily.

To ensure accuracy of the TLD systems, periodic calibration and accuracy checks are performed. For example, all TLDs are checked when new. In addition, the lithium fluoride TLDs are checked, at a minimum, once a year for accurate response to known exposures; the calcium fluoride TLDs are checked, at a minimum, once every 6 months. The calcium fluoride TLD readers are calibrated once a year by one of several calibration facilities, using precision radiation sources directly traceable to the National Institute of Standards and Technology (NIST) and precision TLD standards. The lithium fluoride readers are calibrated to a local source at least once a week, and to a calibration source directly traceable to NIST every 2 years. In addition, checks on the readers are performed daily and during the reading of TLDs to ensure proper reader operation and accuracy, using both an internal electronic standard (built into each reader) and quality control dosimeters that have been exposed to a known exposure level.

In addition to these calibrations and checks, the laboratories and prototypes have an independent quality assurance program to monitor the accuracy of TLDs and the TLD readers in use. TLDs are pre-exposed to exact amounts of radiation by NIST or one of the laboratories and provided to the prototype and/or laboratory for reading. To ensure objectivity, the prototype or laboratory being tested is not told of the radiation values to which each dosimeter has been exposed. The results are then compared to the actual exposures. If these tests find any inaccuracies that exceed established permissible error, appropriate corrective action (such as recalibration of a failed TLD reader) is immediately taken. In addition, the laboratories participate in nationwide intercomparison studies as they are conducted. The results of this program demonstrate that the radiation to which personnel are exposed is being measured by the TLD system with an average error of less than 10 percent.

Pocket ionization chambers with an eyepiece permit wearers to read and keep track of their own radiation exposure during a work period. This pocket dosimeter is required in addition to a TLD when entering a reactor compartment or other high radiation area. The official record of radiation exposure is obtained from the TLD.

Dosimetry devices are worn on the trunk of the body, normally at the waist or chest. In some special situations, additional dosimeters are worn at other locations (for example, on the hands, fingers or head).

Discrepancies that occur between TLD and pocket dosimeter measurements are investigated. These investigations include making independent, best estimates of the worker's exposure, using such methods as time spent in the specific radiation area and comparing the estimates with the TLD and pocket dosimeter measurements to determine which measurement is the more accurate.

In 1975, the conversion from film badges to TLDs for measuring radiation exposure was completed. Before 1975, film packets like those used for dental x-rays were placed in holders designed to allow differentiating between types of radiation. The darkness of the processed film was measured with a densitometer and converted to units of radiation exposure. When the first personnel radiation exposures were measured by Naval Reactors' Department of Energy facilities, there already was widespread photodosimetry experience and precise procedures existed to provide reproducible results.

Each film badge was clearly marked with a name or number corresponding to the individual to whom it was assigned. In high radiation areas every worker also wore a pocket dosimeter, which was read when the worker left the area. At the end of each month when the film badges were processed, the film badge measurements were compared with the sum of the pocket dosimeter readings.

For about 20 years, neutron monitoring at the Naval Reactors' Department of Energy facilities was performed using neutron film badges. These facilities now use lithium fluoride TLDs to monitor neutron exposure of the few personnel exposed to neutron sources, such as for radiation instrument calibration and for reactor plant instrumentation source handling. These measured neutron exposures have been included with gamma radiation exposures in the total whole body radiation exposure discussed in this report, but because neutron exposures are so low, the radiation exposures in this report are nearly all from gamma radiation.

Because personnel at the laboratories can be exposed to both gamma and beta radiation, beta monitoring has been routinely performed using film badges or lithium fluoride TLDs. Monitoring for beta radiation is not normally required at the prototypes, because beta radiation does not penetrate the metal boundaries of the reactor coolant system. Beta radiation needs to be considered in maintenance or repair operations at the prototypes only when systems are opened and personnel are close to surfaces that have been contaminated with radioactive corrosion products from reactor coolant. At the Expended Core Facility, certain remediation operations involve exposure to beta radiation, which may require beta monitoring with lithium fluoride TLDs. In cases where shielding such as clothing, eyeglasses, or plastic contamination control materials can be used to effectively shield the individual from beta radiation, personnel are not monitored for beta radiation. In those cases where the beta radiation cannot be shielded, prototype and Expended Core Facility personnel are monitored with lithium fluoride TLDs provided by the laboratories.

Monitoring for personnel external exposure due to alpha radiation is not performed. Alpha radiation does not penetrate past the dead layer of a person's skin and therefore does not contribute to an individual's external radiation dose.

Physical Examinations

Radiation medical examinations have been required since the beginning of operations by Naval Reactors' Department of Energy facilities for personnel who perform work involving radioactive contamination or have the potential to exceed in 1 year the exposure allowed to a member of the general public (i.e., 0.1 rem). These examinations are conducted in accordance with standard protocols. In these examinations the doctor pays special attention to any condition that might medically disqualify a person from receiving occupational radiation exposure or pose a health risk or safety hazard to the individual or to co-workers, or detrimentally affect the safety of the workplace.

Passing this examination is a prerequisite for obtaining dosimetry, which permits entry to radiation and radiologically controlled areas and allows handling of radioactive material. Few of the military personnel who have already been screened by physical examinations fail this radiation medical examination. For civilian workers, the failure rate is a few percent. However, failure of this examination does not mean a worker will not have a job. Since workers spend most of their time performing non-radioactive work, inability to qualify for radioactive work does not restrict their job opportunities. No worker at Naval Reactors' Department of Energy facilities has been released for inability to pass a radiation medical examination.

When required, radiation medical examinations are given prior to initial work, periodically thereafter, and at termination of radioactive work in the Naval Reactors Program (or at termination of employment). The periodic examinations are conducted in accordance with the following frequencies:

Age	Interval
18-24	Pre-placement
25-49	5 years
50-59	2 years
≥60	1 year

A radiation medical examination includes a review of medical history to determine, among other subjects, past radiation exposure, history of cancer, history of radiation therapy, and family history of cancer. In the medical examination, particular attention is paid to evidence of cancer or a pre-cancerous condition. Laboratory procedures include urinalysis, blood analysis, and comparison of blood constituents to a specific set of standards. If an examination disqualifies an individual, the individual is restricted from receiving occupational radiation exposure.

Radiological Controls Training

Periodic radiological controls training is performed to ensure that all workers understand the general and specific radiological conditions which they might encounter, understand their responsibility to the Naval Reactors Program and the public for safe handling of radioactive materials, understand the risks associated with radiation exposure, and understand their responsibility to minimize their own radiation exposure. Training is also provided on the biological risk of radiation exposure to the unborn child. Before being authorized to perform radioactive work, an employee is required to pass a radiological controls training course, including a written examination. A typical course for workers ranges from 16 to 32 hours. In written examinations on radiological controls, short answer questions (such as multiple choice and true-false) are prohibited. The following are the training requirements for a fully qualified worker:

1. Radiation Exposure Control:

    a. State the limits for whole body penetrating radiation. Explain that the rem is a unit of biological dose from radiation.

    b. Discuss the importance of the individual keeping track of his/her own exposure. Know how to obtain year-to-date exposure information.

    c. Know that local administrative control levels are established to maintain personnel radiation exposure as low as reasonably achievable. Know his/her own exposure control level and who can approve changes to this level.

    d. Discuss procedures and methods for minimizing exposure, such as working at a distance from a source, reducing time in radiation areas, and using shielding.

e. Know that a worker is not authorized to move, modify, or add temporary shielding without specific authorization.

f. Discuss potential sources of radiation associated with work performed by the individual's trade.

g. Discuss the action to be taken if an individual loses dosimetry equipment while in a posted radiation or high radiation area.

h. Discuss how to obtain and turn in dosimetry equipment.

i. Know that thermoluminescent dosimetry equipment is required to be worn on the portion of the individual's body that receives the highest exposure and that pocket dosimeters are worn at the same location on the body as the thermoluminescent dosimetry. Know that only radiological controls personnel can authorize movement of dosimetry equipment from areas of the body where dosimetry is normally worn (such as the chest or waist) to other areas of the body.

j. Be aware of the seriousness of violating instructions on radiation warning signs and unauthorized passage through barriers.

k. Explain how "stay times" are used.

l. Know that naval nuclear work at a facility has no significant effect on the environment or on personnel living adjacent to the facility.

m. Explain the risk associated with personnel radiation exposure. Know that any amount of radiation exposure, no matter how small, might involve some risk; however, exposure within accepted limits represents a risk that is small compared with normal hazards of life. The National Council on Radiation Protection and Measurements has stated that while exposures of workers and the general population should be kept to the lowest practicable levels at all times, the presently permitted exposures limit the risk to a reasonable level in comparison to nonradiation risks. Know that cancer is the main potential health effect of receiving radiation exposure. Know that any amount of radiation exposure to the unborn child, no matter how small the exposure, might involve some risk; however, exposure of the unborn child within accepted limits represents a risk that is small when compared with other risks to the unborn child. Know that the risk to future generations (genetic effect) is considered to be even smaller than the cancer risk and that genetic effects have not been observed in human beings.

n. Know how often an individual shall read his/her pocket dosimeter while in a posted high radiation area. Know that a worker shall leave a posted high radiation area when his/her pocket dosimeter reaches three quarters scale or when a preassigned exposure is reached, whichever is lowest.

o. Know that stay times and predetermined pocket dosimeter readings are assigned when working in radiation fields of 1 rem/hour or greater. Know that the worker shall leave the work area when either the assigned stay time or pocket dosimeter reading is reached.

2. Contamination Control:

   a. Discuss how contamination is controlled during radioactive work (e.g., containment in plastic bags and use of contamination containment areas).

Explain that these controls limit exposure to internal radioactivity to insignificant levels.

b. Discuss how contamination is detected on personnel.

c. Discuss how contamination is removed from objects and personnel.

d. Discuss potential sources of contamination associated with work performed by the individual's trade.

e. State the surface contamination limits. Discuss the meaning of the units of the limits.

f. Explain what radioactive contamination is. Explain the difference between radiation and radioactive contamination.

g. For personnel who are trained to wear respiratory protection equipment, state the controls for use of such equipment. Know that the use of a respirator is based on minimizing inhalation of radioactivity. Know that the respirators used for radiological work are not used for protection in any atmospheres that threaten life or health. Therefore, know that the proper response to a condition in which supply air is lost or breathing becomes difficult is to remove the respirator.

h. Discuss the required checks to determine whether personnel contamination monitoring equipment is operational prior to conducting personnel monitoring. Discuss the action to be taken if the checks indicate the equipment is not operating properly.

i. Discuss the actions to be taken if personnel contamination monitoring equipment alarms while conducting personnel monitoring.

j. Discuss the procedure to package and remove a contaminated item from a controlled surface contamination area.

k. Know that no health effects are expected from receiving radioactive contamination, on the skin, associated with naval nuclear propulsion plants.

l. Discuss the procedures for donning and removing a full set of anticontamination clothing.

3. <u>Accountability of Radioactive Materials</u>: Know that radioactive materials are accounted for when transferred between radiologically controlled areas by tagging, tracking location, and using radioactive material escorts.

4. <u>Waste Disposal</u>:

a. Discuss how individual workers can reduce the amount of radioactive liquid and solid waste generated for the specific type of duties performed.

b. Discuss the importance of properly segregating of non-contaminated, potentially contaminated, and contaminated material.

c. Know what reactor plant reuse water is. Discuss the appropriate uses of reactor plant reuse water.

5. Radiological Casualties:

    a. Discuss the need for consulting radiological controls personnel when questions or problems occur. Understand the importance of complying with the instructions of radiological controls personnel in the event of a problem involving radioactivity.

    b. Discuss procedures to be followed in the event of a spill of material (liquid or solid) which is or might be radioactive.

    c. Discuss procedures to be followed when notified that airborne radioactivity is above the limit.

    d. Discuss procedures to be followed in the event that a high radiation area is improperly controlled.

    e. Discuss actions to be taken when an individual discovers his/her pocket dosimeter is off-scale or has recorded a higher reading than expected.

6. Responsibilities of Individuals: Discuss actions required in order to fulfill the worker's responsibilities. Discuss the responsibility of the individual to notify the Radiation Health Department or the Medical Department of radiation medical therapy, medical diagnosis involving radioisotopes, open wounds or lesions, physical conditions which the worker feels affect his or her qualification to receive occupational radiation exposure, or occupational radiation exposure from past or current outside employment. Discuss the responsibility of the individual to report to area supervision or radiological controls personnel any condition that might lead to or cause avoidable exposure to radiation.

7. Practical Ability Demonstrations: These demonstrations are performed on a mockup.

    a. Demonstrate the ability to read all types of pocket dosimeters used by the organization.

    b. For applicable workers, demonstrate the proper procedure for donning and removing a full set of anticontamination clothing.

    c. Demonstrate the proper procedures for entering and leaving a high radiation area, a radiologically controlled area, and a control point area, including proper procedures for self-monitoring. Demonstrate the ability to read and interpret posted radiation and contamination survey maps.

    d. For applicable workers, demonstrate the ability to properly package and remove an item from a controlled surface contamination area (CSCA).

    e. Demonstrate action to be taken by one or two workers in the event of a spill of radioactive liquid.

    f. For personnel who will enter or remain in areas where respiratory protection equipment is required, demonstrate the proper procedure for inspection and use of the type(s) of respiratory equipment the individual will be required to wear as part of mockup training for the job. This includes demonstrating donning and removing the type of respiratory equipment in conjunction with anticontamination clothing, if anticontamination clothing is required to be worn with the respiratory equipment. In addition, individuals who are trained to wear air-fed hoods demonstrate the proper response to take if supply air is lost while wearing an air-fed hood.

g. For personnel who are trained to work in contamination containment areas, demonstrate the proper procedures for working in these areas. This demonstration includes a pre-work inspection, transfer of an item into the area, a work evolution in the area, and transfer of an item out of the area.

In addition to passing a written examination, completion of this training course requires satisfactory performance during basic types of simulated work operations. To continue as a radiation worker, personnel must requalify in a manner similar to the initial qualification at least every 2 years. Between these qualification periods, personnel are required to participate in a continuing training program, and the effectiveness of that continuing training is validated through random knowledge retention testing. Training is also conducted by individual shop instructors in the specific job skills for radiation work within each trade. For complex jobs this is followed by special training for the specific job, frequently using mockups outside radiation areas.

Radiological controls technicians are required to complete a 6-12 month course in radiological controls, to demonstrate their practical abilities in work operations and drills, and to pass comprehensive written and oral examinations. Radiological controls supervisors are required to have at least the same technical knowledge and abilities as the technicians; however, passing scores for supervisors' examinations are either higher or more difficult to attain than they are for technicians. Oral examinations, which are conducted by radiological controls managers and senior supervisors, require personnel to be able to evaluate symptoms of unusual radiological controls situations. The radiological controls technician or supervisor is required to evaluate initial conditions, state the immediate corrective actions required, state what additional measurements are required, and perform a final analysis of the measurements to identify the specific problem. After qualification, periodic training sessions are required in which all radiological controls technicians and supervisors demonstrate their continued ability to handle situations similar to those covered in the oral examinations. At least every 2½ years, radiological controls personnel must requalify through written and practical abilities examinations similar to those used for initial qualification. Additionally, their first requalification includes an oral examination similar to the one required for initial qualification. Between these qualification periods, radiological controls technicians and supervisors are selected at random for additional written and practical work examinations to assess their retention of knowledge and practical abilities. They also participate in unannounced drills.

In addition to the above training for those who are involved in radioactive work, each person not involved in radioactive work and each person assigned to a prototype (e.g., for training) is required to receive basic radiological training, which is repeated at least annually. This training is to ensure personnel understand the posting of radiological areas, the identification of radioactive materials, and not to cross radiological barriers. This instruction also explains that the radiation environment of personnel outside radiation areas and outside the facility is not significantly affected by nuclear work.

Nuclear Power Training

Before being assigned to a prototype naval nuclear propulsion plant for training, military and civilian personnel are required to pass a 6-month basic training course at the Navy's Nuclear Power School in Charleston, South Carolina. While at Nuclear Power School and continuing while at the prototype, these personnel receive extensive radiological controls training, including lectures, demonstrations, practical work, radiological controls drills, and written and oral examinations. This training emphasizes the ability to apply basic information on radiation and radioactivity.

Before becoming qualified as the shift supervisor of a naval nuclear propulsion prototype plant (that is, the senior contractor supervisor on each shift who is responsible for the timeliness and quality of all training conducted by personnel assigned to his or her crew), the shift supervisor candidate must pass several 8-hour

written examinations and a sequence of oral examinations. A key part of these qualification examinations is radiological controls.

Before serving as plant manager of a naval nuclear propulsion prototype plant, the prospective plant manager attends a 3-month course at the Naval Reactors Program Headquarters. The radiological controls portion of this course covers advanced topics and assumes the individual starts with detailed familiarity with naval nuclear propulsion plant radiological controls. The prospective plant manager must pass both written and oral examinations in radiological controls during this course before assuming the position of plant manager of a naval nuclear propulsion prototype plant.

Radiation Exposure Reduction

Keeping personnel radiation exposures as low as reasonably achievable involves all levels of management at Naval Reactors' Department of Energy facilities. Operations, maintenance, and repair personnel are required to be involved in this subject; it is not left solely to radiological controls personnel. To evaluate the effectiveness of radiation exposure reduction programs, managers use a set of goals. Goals are set in advance to keep each worker's exposure under certain levels and to minimize the number of workers occupationally exposed to radiation. Goals are also set on the total cumulative personnel radiation exposure for each major job and for the whole year. These goals are deliberately made difficult to meet in order to encourage personnel to improve performance.

Of the various goals used, the most effective in reducing personnel radiation exposure has been the use of exposure control levels, which are lower than the Program's quarterly and annual limits. Control levels at Naval Reactors' Department of Energy facilities range from 0.1 rem to 2 rem for the year (depending on the amount of radioactive work scheduled), whereas 5 rem per year is the annual Program limit.

To achieve the benefits of lower control levels in reducing radiation exposure, it is essential to minimize the number of workers permitted to receive radiation exposure. Otherwise, the control levels could be met merely by adding more workers. Organizations are required to conduct periodic reviews to ensure the number of workers is the minimum for the work that has to be performed.

The following is a synopsis of the checklist that has been in use for years to keep personnel radiation exposure as low as reasonably achievable during radiological work.

Preliminary Planning

- Plan well in advance
- Delete unnecessary work
- Determine expected radiation levels

Preparation of Work Procedures

- Plan access to and exit from work area
- Provide for service lines (air, welding, ventilation, etc.)
- Provide communication (sometimes includes closed-circuit television)
- Remove sources of radiation
- Plan for installation of temporary shielding
- Decontaminate
- Work in lowest radiation levels
- Perform as much work as practicable outside radiation areas
- State requirements for standard tools
- Consider special tools
- Include inspection requirements (these identify steps where radiological controls personnel must sign before the work can proceed)

- Minimize discomfort of workers
- Estimate radiation exposure

Temporary Shielding

- Control installation and removal by written procedure
- Inspect after installation
- Conduct periodic radiation surveys
- Minimize damage caused by heavy lead temporary shielding
- Balance radiation exposure received in installation against exposure to be saved by installation
- Shield travel routes
- Shield components with abnormally high radiation levels early in the maintenance period
- Shield the work area based on worker body position
- Perform directional surveys to improve design of shielding by locating sources of radiation
- Use mockup to plan temporary shielding design and installation

Rehearsing and Briefing

- Rehearse
- Use mockup duplicating working conditions
- Use photographs
- Brief workers

Performing Work

- Post radiation levels
- Keep excess personnel out of radiation areas
- Minimize beta radiation exposure (anticontamination clothing effectively shields most beta radiation)
- Supervisors and workers keep track of radiation exposure
- Workers assist in radiation and radioactivity measurements
- Evaluate use of fewer workers
- Reevaluate reducing radiation exposures

Since its inception, the Naval Reactors Program has stressed the reduction of personnel radiation exposure. Measures that have been taken to reduce exposure include standardization of procedures, development of new tooling, improved use of shielding, and compliance with strict contamination control measures. For example, most work involving radioactive contamination is performed in total containment. This practice minimizes the potential for spreading contamination and thus reduces work disruptions, simplifies working conditions, and minimizes the cost of and the exposure during clean up.

Lessons learned during radioactive work and new ways to reduce exposure developed at one organization are made available for use by other organizations in the Naval Reactors Program. This effort allows all of the organizations to take advantage of the experience and developments at one organization and minimizes unnecessary duplication of effort.

The extensive efforts that have been taken to reduce exposure at Naval Reactors' Department of Energy facilities have also had other benefits, such as reduced cost to perform radioactive work and improved reliability. Among other things, detailed work planning, rehearsing, containment, special tools, and standardization have increased efficiency and improved access to perform maintenance, with the overall result that reliability is improved and costs are reduced.

<u>Radiation Exposure Data</u>

The total occupational radiation exposure received by all personnel at Naval Reactors' Department of Energy facilities in 2002 was 129 rem compared to 113 rem in 2001. Tables 2 and 3 summarize radiation exposure received at Naval Reactors' Department of Energy facilities since 1958. The increase in laboratory exposure in 2002 is the result of an increase in facility decontamination and decommissioning workload and increased off-site exposure in support of ship maintenance compared to 2001. The increase in total occupational radiation exposure at the prototypes in 2002 is largely the result of a higher maintenance workload and increased dismantlement effort of former prototypes.

Figure 1 (on page 4) shows the total occupational radiation exposure received at Naval Reactors' Department of Energy facilities. The data show major increases in total radiation exposure in 1964 through 1966 and in 1975. In 1964 through 1966, the increase in the exposures was primarily due to an increase in reactor plant overhaul and refueling efforts. In 1975, the increase was also primarily due to increased overhaul and refueling work; in addition, as noted in the footnote to Table 2, increased occupational exposure occurred in 1974 through 1977 associated with a civil project, the fabrication and installation of the light water breeder reactor (LWBR) at the Shippingport Atomic Power Station. LWBR work was unique because the core was manufactured at Bettis Atomic Power Laboratory (other cores are manufactured by subcontractors) and the fuel was uranium-233 rather than uranium-235. In addition to fabrication, there was also increased radiation exposure due to LWBR installation inside the Shippingport power plant.

Decreases in total annual exposures, numbers of personnel monitored, and numbers of personnel with annual exposures over 2 rem have been achieved as a result of continuing efforts to reduce radiation exposures to the minimum practicable. Since 1979, the total annual exposure for the laboratories has averaged less than 40 rem and for all of the prototype sites has averaged less than 430 rem.

Since a worker usually is exposed to radiation in more than one year, the total number of personnel monitored cannot be obtained by adding the annual numbers. The total number of personnel monitored for radiation exposure associated with Naval Reactors' Department of Energy facilities is about 157,000 (including approximately 94,000 Navy personnel trained as naval nuclear propulsion plant operators at the prototype sites). Table 4 provides further information about the distribution of their radiation exposures. In 2002, more than 99.1 percent of those monitored for radiation received less than 0.5 rem for that year. Since 1958, the average exposure per year for each person monitored has been 0.114 rem—less than the 0.3 rem average annual exposure a person receives from natural background radiation (including the inhalation of radon and its progeny) (reference 10).

Table 4 also lists the numbers of personnel who have exceeded the 3 rem quarterly exposure limit. The total number of persons who have exceeded the quarterly limit since the limit was imposed in 1960 is 14. Of these, 13 personnel had quarterly exposures in the range of 3 to 4 rem, and the person with the highest exposure received 8.1 rem in a quarter; no one has exceeded the quarterly limit since 1973. In none of these cases did personnel exceed the pre-1994 Federal accumulated limit of 5 rem for each year of age over 18, which was also established in 1960. Standard procedures require any person who receives greater than 25 rem in a short time period to be placed under medical observation. No one at Naval Reactors' Department of Energy facilities has ever reached this level. Since it was established in 1967, no one has exceeded Naval Reactors' limit of 5 rem per year for radiation associated with the Naval Reactors Program. The 5 rem per year limit was formally adopted as the Federal limit in 1994.

The average lifetime accumulated radiation exposure for the 157,000 personnel who have been monitored at Naval Reactors' Department of Energy facilities is about 0.324 rem. Although they account for a significant fraction of the radiation exposure received at the prototype sites each year, the approximately 94,000 Navy personnel trained to date receive a small percentage of their lifetime exposure at the prototype sites. The bulk of their exposure is received later in their Navy careers; therefore, their accumulated dose is not representative of the lifetime exposure received by personnel permanently assigned to these facilities. If the Navy trainees are subtracted from the total number of personnel monitored, the average lifetime accumulated exposure from radiation associated with Naval Reactors' Department of Energy facilities is approximately 1 rem. This radiation exposure is much less than the exposure the average American receives from natural background radiation during his or her working lifetime (reference 10).

TABLE 2

OCCUPATIONAL RADIATION EXPOSURE RECEIVED BY PERSONNEL MONITORED AT NAVAL REACTORS' LABORATORIES

Year	Number of Persons Monitored Who Received Exposures in the Following Ranges of Rem for the Year						Total Personnel Monitored	Total Exposure (Rem)[1]
	0-1	1-2	2-3	3-4	4-5	>5[2]		
1958	1,923	74	15	20	8	31	2,071	762
1959	2,050	94	21	16	4	0	2,185	586
1960	2,056	105	43	14	4	3	2,225	581
1961	3,717	120	57	27	9	4	3,934	671
1962	3,956	67	38	13	3	1	4,078	414
1963	5,124	135	47	27	6	1	5,340	647
1964	5,195	265	135	127	52	23	5,797	1,854
1965	5,586	188	36	33	2	0	5,845	977
1966	4,493	105	36	12	3	1	4,650	600
1967	5,006	120	52	34	13	0	5,225	668
1968	4,958	96	44	29	16	0	5,143	606
1969	5,589	72	49	42	26	0	5,778	754
1970	6,346	99	61	39	47	0	6,592	819
1971	7,378	109	48	32	5	0	7,572	646
1972	7,000	138	41	17	2	0	7,198	626
1973	6,867	68	7	0	0	0	6,942	368
1974	7,568	96	28	1	1	0	7,694	221 [3]
1975	4,719	290	151	57	68	0	5,285	280 [3]
1976	5,304	371	88	0	0	0	5,763	219 [3]
1977	4,639	81	5	0	0	0	4,725	201 [3]
1978	3,609	10	0	0	0	0	3,619	143
1979	3,367	4	0	0	0	0	3,371	100
1980	3,330	0	0	0	0	0	3,330	78
1981	2,510	0	0	0	0	0	2,510	72
1982	2,672	0	0	0	0	0	2,672	82
1983	2,717	6	0	0	0	0	2,723	93
1984	2,933	1	0	0	0	0	2,934	67
1985	2,338	4	0	0	0	0	2,342	59
1986	2,261	0	0	0	0	0	2,261	35
1987	2,189	0	0	0	0	0	2,189	27
1988	2,029	0	0	0	0	0	2,029	31
1989	2,108	0	0	0	0	0	2,108	31
1990	2,228	0	0	0	0	0	2,228	28
1991	2,216	0	0	0	0	0	2,216	28
1992	2,162	0	0	0	0	0	2,162	25
1993	2,066	0	0	0	0	0	2,066	22
1994	1,894	0	0	0	0	0	1,894	25
1995	1,853	0	0	0	0	0	1,853	30
1996	1,814	0	0	0	0	0	1,814	19
1997	1,795	0	0	0	0	0	1,795	18
1998	1,778	0	0	0	0	0	1,778	15
1999	2,017	0	0	0	0	0	2,017	17
2000	1,970	0	0	0	0	0	1,970	16
2001	1,856	0	0	0	0	0	1,856	14
2002	1,877	0	0	0	0	0	1,877	16

1. Data for 1958-1962 do not include exposure information for personnel monitored at the Shippingport Atomic Power Station. Data are not available in summary format.
2. Limit for Naval Reactors' Department of Energy facilities was changed to 5 rem per year in 1967.
3. Total radiation exposure for 1974 through 1977 does not include exposure received as part of fabrication and installation of the Light Water Breeder Reactor core at the Shippingport Atomic Power Station. If this exposure is included the totals become 588, 2,660, 1,354, and 524, respectively.

TABLE 3

OCCUPATIONAL RADIATION EXPOSURE RECEIVED BY PERSONNEL
MONITORED AT NAVAL REACTORS'
PROTOTYPE SITES

	Number of Persons Monitored Who Received Exposures in the Following Ranges of Rem for the Year						Total Personnel Monitored	Total Exposure (Rem)[1]
Year	0-1	1-2	2-3	3-4	4-5	>5[2]		
1958	2,415	83	77	50	27	3	2,655	833
1959	2,390	63	18	3	1	0	2,475	420
1960	2,558	126	40	28	2	2	2,756	822
1961	2,600	79	42	13	2	0	2,736	576
1962	3,653	185	45	20	8	4	3,915	1,090
1963	4,354	270	74	29	12	0	4,739	1,332
1964	4,940	203	102	65	16	2	5,328	1,446
1965	5,595	267	110	80	73	58	6,183	2,351
1966	5,765	311	145	81	39	7	6,348	2,099
1967	6,409	241	72	35	12	0	6,769	1,372
1968	6,564	172	69	5	0	0	6,810	1,026
1969	5,713	188	57	9	0	0	5,967	827
1970	5,748	215	82	12	0	0	6,057	1,113
1971	5,499	148	26	1	0	0	5,674	856
1972	7,634	116	3	0	0	0	7,753	773
1973	7,518	181	28	0	0	0	7,727	791
1974	8,427	109	20	9	3	0	8,568	824
1975	7,515	270	131	98	83	0	8,097	1,998
1976	8,282	145	19	0	0	0	8,446	845
1977	8,813	101	17	2	0	0	8,933	782
1978	8,890	157	1	0	0	0	9,048	698
1979	9,908	64	0	0	0	0	9,972	546
1980	9,818	11	0	0	0	0	9,829	433
1981	9,679	2	0	0	0	0	9,681	381
1982	10,464	25	0	0	0	0	10,489	576
1983	10,816	77	0	0	0	0	10,893	660
1984	8,694	13	0	0	0	0	8,707	525
1985	9,136	127	0	0	0	0	9,263	851
1986	8,122	35	0	0	0	0	8,157	576
1987	9,021	47	0	0	0	0	9,068	798
1988	8,328	43	0	0	0	0	8,371	707
1989	7,261	12	0	0	0	0	7,273	451
1990	6,548	73	0	0	0	0	6,621	549
1991	6,369	57	0	0	0	0	6,426	444
1992	5,301	125	0	0	0	0	5,426	458
1993	4,934	133	0	0	0	0	5,067	466
1994	4,368	16	0	0	0	0	4,384	241
1995	3,645	0	0	0	0	0	3,645	203
1996	3,221	37	0	0	0	0	3,258	304
1997	3,450	29	0	0	0	0	3,479	295
1998	3,379	27	0	0	0	0	3,406	241
1999	3,448	7	0	0	0	0	3,455	150
2000	3,216	14	0	0	0	0	3,230	165
2001	3,090	13	0	0	0	0	3,103	99
2002	2,947	22	0	0	0	0	2,969	113

1. Data for 1958-1971 do not include Combustion Engineering personnel monitored at the Windsor Site Operation who did not become employees of KAPL when operation of the Windsor Site was transferred from Combustion Engineering to General Electric.
2. Limit for Naval Reactors' Department of Energy facilities was changed to 5 rem per year in 1967.

TABLE 4

NAVAL REACTORS' DEPARTMENT OF ENERGY FACILITIES
DISTRIBUTION OF PERSONNEL RADIATION EXPOSURE

Year	Average Rem Per Person Monitored[1]		Percent of Personnel Monitored Who Received Greater Than 1 Rem[1]		Number of Personnel Who Exceeded 3 Rem/Quarter
	Prototype	Laboratory	Prototype	Laboratory	
1958	0.314	0.368	9.0	7.1	0
1959	0.170	0.268	3.4	6.2	0
1960	0.298	0.261	7.2	7.6	1
1961	0.211	0.171	5.0	5.5	0
1962	0.278	0.102	6.7	3.0	1
1963	0.281	0.121	8.1	4.0	0
1964	0.271	0.320	7.3	10.4	2
1965	0.380	0.167	9.5	4.4	1
1966	0.331	0.129	9.2	3.4	1
1967	0.203	0.128	5.3	4.2	1
1968	0.151	0.118	3.6	3.6	0
1969	0.139	0.130	4.3	3.3	0
1970	0.184	0.124	5.1	3.7	5
1971	0.151	0.085	3.1	2.6	1
1972	0.100	0.087	1.5	2.8	0
1973	0.102	0.053	2.7	1.1	1
1974	0.096	0.076	1.6	1.6	0
1975	0.247	0.503	7.2	10.7	0
1976	0.100	0.235	1.9	8.0	0
1977	0.088	0.111	1.3	1.8	0
1978	0.077	0.040	1.7	0.3	0
1979	0.055	0.030	0.6	0.1	0
1980	0.044	0.023	0.1	0.0	0
1981	0.039	0.029	0.0	0.0	0
1982	0.055	0.031	0.2	0.0	0
1983	0.061	0.034	0.7	0.2	0
1984	0.060	0.023	0.1	0.0	0
1985	0.092	0.025	1.4	0.2	0
1986	0.071	0.015	0.4	0.0	0
1987	0.088	0.012	0.5	0.0	0
1988	0.084	0.015	0.5	0.0	0
1989	0.062	0.015	0.2	0.0	0
1990	0.083	0.013	1.1	0.0	0
1991	0.069	0.013	0.9	0.0	0
1992	0.084	0.012	2.3	0.0	0
1993	0.092	0.011	2.6	0.0	0
1994	0.055	0.013	0.3	0.0	0
1995	0.056	0.016	0.0	0.0	0
1996	0.093	0.011	1.1	0.0	0
1997	0.085	0.010	0.8	0.0	0
1998	0.071	0.008	0.8	0.0	0
1999	0.043	0.008	0.2	0.0	0
2000	0.051	0.008	0.4	0.0	0
2001	0.032	0.008	0.4	0.0	0
2002	0.038	0.009	0.7	0.0	0
Average	0.117	0.110	2.4	2.8	
Overall Average	0.114		2.5		

1. Laboratory data for 1958-1962 do not include exposure information for personnel monitored at the Shippingport Atomic Power Station. Data are not available in summary format. Prototype data for 1958-1971 does not include Combustion Engineering personnel monitored at the Windsor Site Operation who did not become employees of KAPL when operation of the Windsor Site was transferred from Combustion Engineering to General Electric.

Table 5 provides information on the distribution of lifetime accumulated exposures for all personnel who were monitored in 2002 for radiation exposure associated with Naval Reactors' Department of Energy facilities.

TABLE 5

LIFETIME RADIATION EXPOSURE ASSOCIATED WITH NAVAL REACTORS' DEPARTMENT OF ENERGY FACILITIES

Range of Accumulated Lifetime Radiation Exposures (Rem)	Percentage of Personnel Monitored in 2002 with Lifetime Accumulated Radiation Exposure Within that Range
0 – 5	96.16
5 – 10	2.83
10 – 15	0.66
15 – 20	0.21
20 – 30	0.10
30 – 40	0.02
40 – 50	0.02
50 – 60	0.00
> 60	0.00

The Federal radiation exposure limits used in the U.S. until the 1994 changes to the Code of Federal Regulations, Title 10, Part 20, limited an individual's lifetime exposure to 5 rem for each year beyond age 18. With the 1994 changes, lifetime exposure is not specifically limited, but is controlled as the result of the annual limit of 5 rem. In their most recent radiation protection recommendations, the National Council on Radiation Protection and Measurements (NCRP) recommends that organizations to control lifetime accumulated exposure to less than 1 rem times the person's age (reference 11). Among all personnel monitored in 2002, there is currently no worker with a lifetime accumulated exposure greater than the NCRP recommended level of 1 rem times his or her age from radiation associated with the Naval Reactors Program.

INTERNAL RADIOACTIVITY

Policy and Limits

Naval Reactors' policy on internal radioactivity for personnel associated with Naval Reactors' Department of Energy facilities continues to be the same as it was more than four decades ago--to prevent significant radiation exposure to personnel from internal radioactivity. The limits invoked to achieve this objective are one-tenth of the levels allowed by Federal regulations for radiation workers. Since 1972, no one has received more than one-tenth the Federal annual internal occupational exposure limit from internal radiation exposure caused by radioactivity associated with work at Naval Reactors' Department of Energy facilities.

Before 1972, two individuals had internal depositions between 50 and 80 percent of the Maximum Permissible Lung Burden (MPLB), and three individuals had internal depositions ranging from 10 to 50 percent of the MPLB[1]; no one had a deposition that exceeded the MPLB. The MPLB is the level of radioactivity retained in the individual's lung that would result in an exposure to the person's lung equal to the dose limit for the lung of 15 rem per year if the radioactivity level remained constant throughout the year. Additionally, one individual received a very high localized exposure to his ear drum in 1955 as a result of a fine particle of radioactive material which became lodged in his ear canal for approximately 9 days. Although there is no explicit limit for radioactivity deposited in a person's ear, this case resulted in partial hearing loss. This case is discussed further on page 41.

As discussed above for the lungs, the basic Federal limit for radiation exposure to organs of the body from internal radioactivity was 15 rem per year prior to 1994. There have been higher levels applied at various times for thyroid and for bones; however, use of these specific higher limits was not necessary at Naval Reactors' Department of Energy facilities.

The limit recommended for most organs of the body by the U.S. National Committee on Radiation Protection and Measurements in 1954 (reference 1), by the U.S. Atomic Energy Commission in the initial edition of reference (3) applicable in 1957, and by the International Commission on Radiological Protection in 1959 (reference 2) was 15 rem per year. This limit was adopted for Federal agencies when President Eisenhower approved recommendations of the Federal Radiation Council May 13, 1960.

In 1977, the International Commission on Radiological Protection revised its recommendations (reference 8), particularly regarding internal exposure. The new recommendations provided a method of combining, and controlling, exposure from internal radioactivity with exposure from external radiation. The effect of the 1977 recommendations was to raise the allowable dose to many organs, with no organ allowed to receive more than 50 rem in a year. In conjunction with these recommendations, more recent knowledge on the behavior and effect of internal radioactivity was used to derive new limits for its control (reference 12). The Federal guidance approved by President Reagan in 1987 adopted these revised recommendations and methods (reference 9), and were incorporated as Federal limits in 1994.

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1. One Knolls Atomic Power Laboratory individual was reported to the Department of Energy in 1982 as exceeding 50 percent of the Maximum Permissible Lung Burden (MPLB) for the year 1969. In 1988, the Laboratory reassessed this case. This assessment found the original internal monitoring analysis, performed by a subcontractor, had a systematic high bias. Taking this high bias into account, the 1988 assessment was that no intake greater than 10 percent of the MPLB had occurred.

Sources of Radioactivity at Prototypes

Radioactivity can get inside the body through air, through water or food, and through surface contamination via the mouth, skin, or a wound. The radioactivity of primary concern at the prototypes is the activated metallic corrosion products on the inside surfaces of reactor plant piping systems. These are in the form of insoluble metallic oxides, primarily iron oxides. Reference 13 contains more details on why cobalt-60 is the radionuclide of most concern for internal radioactivity.

The design conditions for reactor fuel are much more severe for warships than for commercial power reactors. Naval nuclear propulsion prototype plants are built to the same high standards as nuclear-powered warships. As a result of being designed to withstand shock, naval reactor fuel elements retain fission products including fission gases within the fuel. Sensitive measurements are frequently made to verify the integrity of reactor fuel. Consequently, fission products such as strontium-90 and cesium-137 make no measurable contribution to internal exposure of personnel from radioactivity associated with naval nuclear propulsion prototype plants. Similarly, alpha emitting radioisotopes such as uranium and plutonium are retained within the fuel elements and are not accessible to personnel operating or maintaining a naval nuclear propulsion prototype plant.

Because of the high integrity of reactor fuel and because soluble boron is not used in reactor coolant for normal reactivity control in naval nuclear propulsion prototype plants, the amount of tritium in reactor coolant is far less than in typical commercial power reactors. The small amount that is present is formed primarily as a result of neutron interaction with the deuterium naturally present in water. The radiation from tritium is of such low energy that the Federal limits for breathing or swallowing tritium are more than three hundred times higher than for cobalt-60. As a result, radiation exposure to personnel from tritium is far too low to measure. Similarly, the low-energy beta radiation from carbon-14, which is formed in small quantities in reactor coolant systems as a result of neutron interactions with nitrogen and oxygen, does not add measurable radiation exposure to personnel operating or maintaining naval nuclear propulsion prototype plants.

At the Expended Core Facility, the radioactivity of primary concern is from radionuclides associated with irradiated nuclear fuel. Highly trained, specialized personnel examine and evaluate the reactor cores removed from nuclear-powered submarines, aircraft carriers, and prototype plants. These evaluations are performed to obtain important technical data to verify and improve the design of nuclear cores. Although the quantity of radioactive material handled is large, advanced personnel radiological training, radiological engineering designs (e.g., shielded cells and special handling equipment), and radiological monitoring programs (e.g., air monitoring systems) prevent any significant internal exposure.

Sources of Radioactivity at Laboratories

The radionuclides of primary concern at the laboratories are those associated with the nuclear fuel process; these include the fuel itself (uranium-234, uranium-235, and uranium-238) and the principal fission products (strontium-90 and cesium-137). Radioactivity with more restrictive limits than the above radionuclides (e.g., thorium and plutonium) is also present at the laboratories, but only in isolated and specially controlled operations. Highly trained, specialized personnel design and test new fuel systems and verify the integrity of existing materials. Laboratory personnel handle only small quantities of fuel. The small quantities handled coupled with advanced personnel radiological training, radiological engineering designs (e.g. containment boxes), and radiological monitoring programs (e.g. air monitoring systems) prevent any significant internal exposure.

Residues of the radionuclides described above are present at low levels in some laboratory equipment and facilities that were used for radioactive work in the past. Radiological cleanup is being undertaken to remove these radioactive materials. This effort is performed in a carefully controlled manner; the radiological controls techniques followed during this work (e.g., special radiological training, formal procedures, radiological engineering designs) are designed to prevent any significant internal exposure.

Control of Airborne Radioactivity

Airborne radioactivity is controlled during routine operations such that respiratory equipment is not normally required. To prevent exposure of personnel to airborne radioactivity, contamination containment tents, bags, or boxes are used. These containments are ventilated to the atmosphere through high efficiency filters that have been designed and tested to remove at least 99.95 percent of particles of a size comparable to cigarette smoke. Radiologically controlled areas such as reactor compartments are also required to be ventilated through high efficiency filters anytime work that could cause airborne radioactivity is in progress. Airborne radioactivity surveys are required to be performed regularly in radioactive work areas. Anytime airborne radioactivity above the limit is detected in occupied areas, work that might be causing airborne radioactivity is stopped. This conservative action is taken to minimize internal radioactivity even though the Naval Reactors' airborne radioactivity limit would allow continuous breathing for 40 hours per week throughout the year to reach an annual exposure of one-tenth the Federal limit. Personnel are also trained to use respiratory equipment when airborne radioactivity above the limit is detected. However, respiratory equipment is seldom needed and is not relied upon as the first line of defense against airborne radioactivity.

It is not uncommon for airborne radioactivity to be caused by radon naturally present in the air. Atmospheric conditions such as temperature inversions can allow the buildup of radioactive particles from radon to occur. Radon can also build up in sealed or poorly ventilated rooms in homes or buildings made of stone or concrete, or it can migrate from the underlying ground. In fact, most cases of airborne radioactivity above Naval Reactors' conservative airborne radioactivity limit in occupied areas have been caused by atmospheric radon, which has a higher airborne concentration limit, and not from prototype plant or laboratory operations. Procedures have been developed to reduce the radon levels when necessary and to allow work to continue after it has been confirmed that the elevated airborne radioactivity is from naturally occurring radon.

Control of Radioactive Surface Contamination

Perhaps the most restrictive regulations in Naval Reactors' radiological controls program are for controlling radioactive contamination. Work operations involving potential for spreading radioactive contamination use containments to prevent personnel contamination or the generation of airborne radioactivity. The controls for radioactive contamination are so strict that precautions sometimes have had to be taken to prevent tracking contamination from the world's atmospheric fallout and natural sources outside radiological areas *into* radiological spaces because the contamination control limits used in these areas were below the levels of fallout and natural contamination occurring outside in the general public areas.

Anticontamination clothing, including coveralls, hoods (to cover the head, ears and neck), shoe covers and gloves, is provided when needed. However, the basic approach is to avoid the need for anticontamination clothing by containing the radioactivity. As a result, most work on radioactive materials is performed with hands reaching into gloves installed in containments, making it unnecessary for the worker to wear anticontamination clothing. In addition to providing better control over the spread of radioactivity, this method has reduced radiation exposure because the worker can usually do a job better and faster in normal work clothing. A basic requirement of

contamination control is to monitor all personnel leaving any area where radioactive contamination could possibly occur. Workers are trained to survey themselves (i.e., frisk), and their performance is checked by radiological controls personnel. Frisking of the entire body is required upon leaving an area with radioactive surface contamination, normally using sensitive hand-held survey instruments. Major work facilities are equipped with portal monitors, which are used in lieu of hand-held friskers. Personnel monitor before, not after, they wash. Therefore, washing or showering at the exit of radioactive work areas is not required. The basic philosophy is to prevent contamination, not wash it away.

Trained radiological controls personnel frequently survey for radioactive contamination. These surveys are reviewed by senior personnel to doublecheck that no abnormal conditions exist. The instruments used for these surveys are checked against a radioactive calibration source daily and prior to use, and they are calibrated at least every 6 months.

Control of Food and Water

Smoking, eating, drinking, and chewing are prohibited in radioactive areas. By prohibiting these hand-to-mouth contacts, the possibility of internal contamination is reduced even further.

Wounds

Skin conditions or open wounds, which might not readily be decontaminated, are cause for temporary or permanent disqualification from doing radioactive work. Workers are trained to report such conditions to radiological controls or medical personnel, and radiological controls technicians watch for open wounds when workers enter radioactive work areas. In the initial medical examination prior to radiation work and during subsequent examinations, skin conditions are also checked. If the cognizant local medical officer determines that a wound is sufficiently healed or considers the wound is adequately protected, he may remove the temporary disqualification.

There have been only a few cases of contaminated wounds at Naval Reactors' Department of Energy facilities. In most years, none occur. Examples of such injuries that have occurred in the past include a scratched hand, a metallic sliver in a hand, a cut finger, and a puncture wound to a hand. These wounds occurred at the same time the person became contaminated. Insoluble metallic oxides that make up the radioactive contamination remain primarily at the wound site rather than being absorbed into the blood stream. Most contaminated wounds have been promptly and easily decontaminated.

Monitoring for Internal Radioactivity at Prototypes

The radionuclide of most concern for internal radiation exposure from naval nuclear propulsion prototype plants is cobalt-60. Although most radiation exposure from cobalt-60 inside the body will be from beta radiation, the gamma radiation given off makes cobalt-60 easy to detect. Complex whole body counters are not required to detect cobalt-60 at low levels inside the body. For example, one-millionth of a curie of cobalt-60 inside the lungs or intestines will cause a measurement of two times above the background reading with the standard hand-held survey instrument used for personnel frisking. This amount of internal radioactivity will cause the instrument to reach the alarm level. Every person is required to monitor the entire body upon leaving an area with radioactive surface contamination. Monitoring the entire body (not just the hands and feet) is a requirement at Naval Reactors' Department of Energy facilities. Therefore, if a person had as little as one-millionth of a curie of cobalt-60 internally, it would readily be detected.

Swallowing one-millionth of a curie of cobalt-60 will cause internal radiation exposure to the gastro-intestinal tract of about 0.08 rem. The radioactivity will pass through the body and be excreted within a period of a little more than a day. Since 1994, Federal regulations limit organ exposure from internal radioactivity to 50 rem per year.

One-millionth of a curie of cobalt-60 still remaining in the lungs 1 day after an inhalation incident is estimated to cause a radiation exposure of about 2 rem to the lungs over the following year and 6 rem total over a lifetime, based on standard calculations recommended by the International Commission on Radiological Protection (reference 12). Since 1994, Federal regulations limit organ exposure from internal radioactivity to 50 rem per year. These techniques provide a convenient way to estimate the radiation exposure a typical individual might be expected to receive from small amounts of internally deposited radioactivity. These techniques account for the gradual removal of cobalt-60 from the lungs through biological processes and the radioactive decay of cobalt-60 with a 5.3 year half-life. However, if an actual case were to occur, the measured biological elimination rate would be used in determining the amount of radiation exposure received.

In addition to the control measures to prevent internal radioactivity and the frisking frequently performed by those who work with radioactive materials, more sensitive internal monitoring is also performed. Equipment designed specifically for monitoring internal radioactivity uses a type of gamma radiation sensitive scintillation detector that will reliably detect inside the body an amount of cobalt-60 more than 100 times lower than the one-millionth of a curie used in the examples above. Naval Reactors' prototype sites monitor each employee for internal radioactivity before initially performing radiation work, after terminating radiation work, and periodically in between.

Any person at the prototype who has radioactive contamination above the limit anywhere on the skin of his or her body during regular monitoring at the exit from a radiologically controlled area is monitored for internal radioactivity with the sensitive internal monitoring equipment. Also any person who might have breathed airborne radioactivity above limits is monitored with the sensitive equipment.

Internal monitoring equipment is calibrated each work shift the equipment is in use. This calibration involves checking the equipment's response to a known source of radiation. In addition, Naval Reactors has an independent quality assurance program in which prototype organizations performing internal monitoring are tested on a periodic basis. This testing involves monitoring a human-equivalent torso phantom, which contains an amount of radioactivity traceable to standards maintained by the National Institute of Standards and Technology. The exact amount of radioactivity in the test phantom is not divulged to the organization being tested until after the test is complete. Any inaccuracies found by these tests that exceed established permissible error limits are investigated and corrected.

Monitoring for Internal Radioactivity at Laboratories

The radionuclides of most concern for internal radiation exposure from laboratory operations include uranium isotopes (uranium-234, uranium-235, and uranium-238) and fission products (primarily strontium-90 and cesium-137). Uranium isotopes are principally alpha emitters. Alpha particles deposit their energy over a much shorter distance than beta or gamma rays because alpha particles are considerably larger in size and have a much greater charge. Fission products emit beta and gamma radiation similar to cobalt-60.

Although uranium-235 is principally an alpha emitter, it also emits several low-energy gamma rays. Thorium-234, a daughter of uranium-238, also emits low-energy gamma radiation. This low-energy gamma radiation can be detected with sensitive scintillation or semiconductor detectors. For internal monitoring, each laboratory employs a state-of-the-art low-energy gamma radiation detection system in a shielded enclosure. These

systems are designed to detect levels of uranium in the lungs at levels less than one billionth of a curie. In addition, other systems allow for the detection of higher energy, gamma radiation emitting fission products such as cesium-137 at roughly the same sensitivity as uranium-235. In addition to this type of internal exposure monitoring, personnel who work with certain forms of radioactivity are also required to submit periodic urine samples for extremely sensitive radionuclide analysis. Fecal analysis is also sometimes performed as discussed below. As a measure of the sensitivity of laboratory internal monitoring techniques, the systems used to measure radioactivity in urine and fecal samples are able to measure one ten-trillionth of a curie per liter for urine and one trillionth of a curie per gram for feces. The dose that corresponds to these levels is less than 0.015 rem to the lungs over the following year and 0.075 rem over a lifetime, when monitoring is conducted within 24 hours of a potential internal exposure event.

The laboratories require personnel to be internally monitored before initially assuming duties involving radiation exposure, upon terminating from such duties, and periodically in between. The frequency at which personnel are monitored is determined by their assigned duties. Those personnel who work with radioactive materials more often are monitored more frequently. In addition, like the prototype sites, any person who has radioactive contamination above the limit anywhere on their skin or who might have been exposed to airborne radioactivity above the limit is immediately monitored with the sensitive detector system; these individuals are also required to submit urine and fecal samples as appropriate for the radionuclides involved.

Internal monitoring equipment is calibrated and the calibration is checked each day the equipment is in use. This process involves checking the equipment's response to a known source of radiation. In addition, background checks are performed daily during equipment usage to further verify system performance.

Although internal monitoring is routinely performed at Naval Reactors' Department of Energy facilities, internal monitoring results are not used to control personnel radiation exposure below limits. Rather, work is engineered to prevent radioactivity from becoming internally deposited, and the monitoring is performed to verify that no radioactivity is present.

Results of Internal Monitoring in 2002

During 2002, 1,910 personnel were monitored for internally deposited radioactivity. One worker monitored had internally deposited radioactivity associated with work at Naval Reactors’ Department of Energy facilities. The worker had an intake of 0.26 percent of the Federal annual limit on intake (ALI), resulting in a committed effective dose equivalent of 13 mrem. This dose is less than the dose someone would receive in 2 weeks from natural background sources of radiation. No other personnel monitored had internally deposited radioactivity detected greater than a tenth of a percent (0.1 percent) of the Federal ALI from radioactivity associated with work at Naval Reactors' Department of Energy facilities.

EFFECTS OF RADIATION ON PERSONNEL

Control of radiation exposure at Naval Reactors' Department of Energy facilities has always been based on the assumption that any exposure, no matter how small, may involve some risk; however, exposure within the accepted exposure limits represents a risk small in comparison with the normal hazards of life. The basis for this statement is presented below.

Exposure to Radiation May Involve Some Risk

Since the inception of nuclear power, scientists have cautioned that exposure to ionizing radiation in addition to that from natural background may involve some risk. The U.S. National Committee on Radiation Protection and Measurements in 1954 (reference 1) and the International Commission on Radiological Protection in 1958 (reference 2) both recommended that exposures should be kept as low as practicable and that unnecessary exposure should be avoided to minimize this risk. The International Commission on Radiological Protection in 1962 (reference 14) explained the assumed risk as follows:

> The basis of the Commission's recommendations is that any exposure to radiation may carry some risk. The assumption has been made that, down to the lowest levels of dose, the risk of inducing disease or disability in an individual increases with the dose accumulated by the individual, but is small even at the maximum permissible levels recommended for occupational exposure.

The National Academy of Sciences-National Research Council Advisory Committee on the Biological Effects of Ionizing Radiations included similar statements in its reports in the 1956-1961 period and most recently in 1990 (reference 15). In 1960, the Federal Radiation Council stated (reference 4) that its radiation protection guidance did not differ substantially from recommendations of the National Committee on Radiation Protection and Measurements, the International Commission on Radiological Protection, and the National Academy of Sciences. This statement was again reaffirmed in 1987 (reference 9).

One conclusion from these reports is that radiation exposures to personnel should be minimized, but this is not a new conclusion. It has been a major driving force of the Naval Reactors Program since its inception.

Radiation Exposure Comparisons

The success of Naval Reactors' Department of Energy facilities in minimizing exposures to personnel can be evaluated by making some radiation exposure comparisons.

Annual Exposure

One important measure of personnel exposure is the amount of exposure an individual receives in a year. Tables 2 and 3 show that since 1979, no individual has received more than 2 rem in a year as a result of working at Naval Reactors' Department of Energy facilities. Also, from Table 4 it can be seen that the average exposure per person monitored since 1979 is 0.066 rem for prototype personnel and 0.018 rem for laboratory personnel; the overall average annual exposure is 0.053 rem. The following comparisons give perspective on these individual annual doses in comparison to Federal limits and other exposures:

- The Naval Nuclear Propulsion Program limits an individual’s dose to 3 rem in one ***quarter***. No one in the Naval Reactors' Program has exceeded 2 rem in one ***year*** since 1979—less than half the Federal annual limit of 5 rem.

- No one at Naval Reactors' Department of Energy facilities has exceeded 2 rem in a year since 1979. Annually between 195 and 7,500 workers at NRC-licensed commercial nuclear-powered reactors have exceeded 2 rem in various years over this same period (reference 16).
- The average annual exposure since 1979 of 0.053 rem is:
  - approximately 1 percent of the Federal annual limit of 5 rem.
  - less than half the average annual exposure of commercial nuclear power plant personnel (reference 16).
  - less than one-third the average annual exposure received by commercial airline flight crew personnel due to cosmic radiation (reference 17).

For additional perspective, the annual exposures for personnel at Naval Reactors' Department of Energy facilities may also be compared to natural background and medical exposures:

- The maximum annual exposure of 2 rem is less than half the annual exposure from natural radioactivity in the soils in some places in the world, such as Tamil Nadu, India and Meaipe, Brazil (reference 15).
- The average annual exposure since 1979 of 0.053 rem is:
  - one-sixth the average annual exposure to a member of the population in the U.S. from natural background radiation (reference 21).
  - less than half the exposure from common diagnostic medical x-ray procedures such as x-rays of the back (reference 22).
  - less than the difference in the annual exposure due to natural background radiation between Denver, Colorado, and Washington, D.C. (reference 21).
- The average **annual** exposure of 0.018 rem for laboratory personnel is less than the **monthly** exposure to a member of the population in the U.S. from natural background radiation (reference 21).

Collective Dose

The sum of all individual exposures gives the collective dose. Collective dose may be used as a measure of the theoretical effect on the personnel occupationally exposed at Naval Reactors' Department of Energy facilities taken as a group, and is an indicator of the effectiveness of the Program's efforts to minimize radiation exposure. From Tables 2 and 3, it can be seen that the collective dose received by all 4,846 personnel monitored at Naval Reactors' Department of Energy facilities in 2002 was 129 rem. The following comparisons give perspective on this collective dose in comparison to collective doses from other occupations. This annual collective dose is:

- less than one-fourth the average annual collective dose received by a comparable number of commercial nuclear power plant personnel (reference 16).
- less than half the average annual collective dose received by a comparable number of persons in the medical field (reference 17).
- less than one-sixth the average annual collective dose received by a comparable number of commercial airline flight crew personnel (reference 17).

For even further perspective, the annual collective dose to personnel at Naval Reactors' Department of Energy facilities may also be compared to collective doses from radiation exposures not related to an individual's occupation. This annual collective dose is:

- less than 10 percent of the average annual collective dose of 1,454 rem received by a comparable number of individuals in the U.S. population due to natural background radiation (reference 21).
- less than 20 percent of the average annual collective dose of 630 rem received by a comparable number of individuals in the U.S. population due to diagnostic medical procedures such as x-rays of the back (reference 22).
- approximately 2 percent of the average annual collective dose of 6,300 rem received by a comparable number of average smokers due to the natural radioactivity in tobacco smoke (reference 10) (rough comparison due to the difficulty in estimating the average annual collective dose received from smoking).

Conclusions on Radiation Exposure to Personnel

The preceding comparisons show that occupational exposures to individuals working at Naval Reactors' Department of Energy facilities are small when compared to other occupational exposures and limits, and are within the range of exposures from natural background radiation in the U.S. and worldwide. Additionally, the total dose to all persons (collective dose) each year is small compared to the collective doses to workers in other occupations, and insignificant compared to the collective doses to the U.S. population from natural background radiation, medical procedures, and tobacco smoke. In reference 17 the National Council on Radiation Protection and Measurements reviewed the exposures to the U.S. working population from occupational exposures. This included a review of the occupational exposures to personnel from the Naval Nuclear Propulsion Program. Based on this review, the National Council on Radiation Protection and Measurements concluded:

> These small values (of occupational exposure) reflect the success of the Navy's efforts to keep doses as low as reasonably achievable (ALARA).

The same success achieved by the Naval Nuclear Propulsion Program for occupational radiation exposure to Navy personnel has also been achieved for the personnel at Naval Reactors' Department of Energy facilities.

Studies of the Effects of Radiation on Human Beings

Observations on the biological effects of ionizing radiation began soon after the discovery of x-rays in 1895 (reference 15).

Numerous references are made in the early literature concerning the potential biological effects of exposure to ionizing radiation. These effects have been intensively investigated for many years (reference 23). Although there still exists some uncertainty about the exact level of risk, the National Academy of Sciences stated in reference 24:

> It is fair to say that we have more scientific evidence on the hazards of ionizing radiation than on most, if not all, other environmental agents that affect the general public.

A large amount of experimental evidence of radiation effects on living systems has come from laboratory studies on cell systems and on animals. However, what sets our extensive knowledge of radiation effects on human beings apart from other hazards is the evidence obtained from studies of human populations that have been exposed to radiation in various ways (reference 24). The health effects demonstrated from studies

of people exposed to high doses of radiation (that is, significantly higher than current occupational limits) include the induction of cancer, cataracts, sterility, and developmental abnormalities from prenatal exposure. Animal studies have also documented the potential for genetic effects.

Near the end of 1993, the Secretary of Energy requested the disclosure of all records and information on radiation experiments involving human subjects performed or supported by the Department of Energy or predecessor agencies. The Naval Reactors Program has never conducted or supported any radiation experiments on human beings. As discussed in this report, the Program has adopted exposure limits recommended by national and international radiation protection standards committees (such as the National Council on Radiation Protection and Measurements, and the International Commission on Radiological Protection) and has relied upon conservative designs and disciplined operating and maintenance practices to minimize radiation exposure to levels well below these limits.

High-Dose Studies

The human study populations that have contributed a large amount of information about the biological effects of radiation exposure include the survivors of the atomic bombings of Hiroshima and Nagasaki; x-rayed tuberculosis patients; victims of various radiation accidents, patients that have received radiation treatment for a variety of diseases, radium-dial painters, and inhabitants of South Pacific islands that received unexpected doses from fallout due to early nuclear weapons tests. All of these populations received high or very high exposures.

The studies of atomic bomb survivors have provided the single most important source of information on the immediate and delayed effects of whole body exposure to ionizing radiation. The studies have been supported for over 40 years by the U.S. and Japanese Governments and include analysis of the health of approximately 100,000 survivors of the bombings. Continued followup of the Japanese survivors has changed the emphasis of concern from genetic effects to the induction of cancer (references 15 and 18).

The induction of cancer has been the major latent effect of radiation exposure in the atomic bomb survivors. The tissues most sensitive to the induction of cancer appear to be the blood-forming organs, the thyroid, and the female breast. Other cancers linked to radiation, but with a lower induction rate, include cancers of the lung, stomach, colon, bladder, liver, and ovary. A wave-like pattern of leukemia induction was seen over time beginning approximately 2 years after exposure, peaking within 10 years of exposure, and generally diminishing to near baseline levels over the next 40 years. For other cancers, a statistically significant excess was observed 5-10 years or more after exposure, and the excess risk continues to rise slowly with time (reference 18).

While it is often stated that radiation causes all forms of cancer, many forms of cancer actually show no increase among atomic bomb survivors. These include chronic lymphocytic leukemia, Hodgkin's disease, and cancers of the pancreas, prostate, cervix, and testes (reference 18).

To understand the impact of cancer induction from the atomic bombings in 1945, it is necessary to compare the number of radiation-related cancers to the total number of cancers expected in the exposed group. In studies of approximately 50,000 survivors with doses ranging from 0.5 to over 200 rem, approximately 6,900 cases of solid cancer have been identified as of 1994. Of these, roughly 700 are in excess of expectation (reference 19). Also within this population, there were 4,565 solid cancer deaths and 176 leukemia deaths as of 1990 (reference 20). Of these, an estimated 376 solid cancer deaths and 78 leukemia deaths are in excess of expectation (reference 20). These studies did not reveal a statistically significant excess of cancer below doses of 6 rem (reference 18). The cancer mortality experience of the other human study

populations exposed to high doses (referenced above) is generally consistent with the experience of the Japanese atomic bomb survivors (reference 18).

About 40 years ago, the major concern of the effects from radiation exposure centered on possible genetic changes. Ionizing radiation was known to cause such effects in many species of plants and animals. However, intense study of nearly 70,000 offspring of atomic bomb survivors has failed to identify any increase in genetic effects. Based on a recent analysis, human beings now appear less sensitive to the genetic effects from radiation exposure than previously thought (reference 15).

Radiation-induced cataracts have been observed in atomic bomb survivors and persons treated with very high doses of x-rays to the eye. Based on this observation, potential cataract induction was considered a matter of concern. However, more recent research indicates that the induction of cataracts by radiation requires a high threshold dose. The National Academy of Sciences has stated that unless the protracted exposure to the eye exceeds the threshold of 800 rem, vision-impairing cataracts will not form. This exposure greatly exceeds the amount of radiation that can be accumulated by the lens through occupational exposure to radiation under normal working conditions (reference 15).

Radiation damage to the reproduction cells at very high doses has been observed to result in sterility. Impairment of fertility requires a dose large enough to damage or deplete most of the reproductive cells and is close to a lethal dose if exposure is to the whole body. The National Academy of Sciences estimates the threshold dose necessary to induce sterility is approximately 350 rem, or possibly more, in a single dose (reference 15). As in the case of cataract induction, this dose far exceeds the dose that can be received from occupational exposure under normal working conditions.

Among the atomic bomb survivors' children who received high prenatal exposure (that is, their mothers were pregnant at the time of the exposure), developmental abnormalities were observed. These abnormalities included stunted growth, small head size, and mental retardation. Additionally, recent analysis suggests that during a certain stage of development (the 8th to 15th week of pregnancy) the developing brain appears to be especially sensitive to radiation. A slight lowering of IQ might follow doses of 10 rem or more (reference 15).

From this discussion of the health effects observed in studies of human populations exposed to high doses of radiation, it can be seen that the most important of the effects from the standpoint of occupationally exposed workers is the potential for induction of cancer (reference 15).

Low-Dose Studies

The cancer-causing effects of radiation on the bone marrow, female breast, thyroid, lung, stomach and other organs reported for the atomic bomb survivors are similar to findings reported for other irradiated human populations. With few exceptions, however, the effects have been observed only at high doses and high dose rates. Studies of populations chronically exposed to low-level radiation have not shown consistent or conclusive evidence of an associated increase in the risk of cancer (reference 15). Attempts to observe increased cancer in a human population exposed to low doses of radiation have been difficult.

One problem in such studies is the number of people needed to provide sufficient statistics. As the dose to the exposed group decreases, the number of people needed to detect an increase in cancer goes up at an accelerated rate. For example, for a group exposed to 1 rem (equivalent to the average lifetime accumulated dose for an individual working at a Naval Reactors' Department of Energy facility), it would take more than 500,000 people in order to detect an excess in lung cancers (based on

current estimates of the risk (reference 25). This is more than three times the number of persons that have performed radioactive work at all of the Naval Reactors' Department of Energy facilities over the last 48 years. Another limiting factor is the relatively short time since low-dose occupational exposure started being received by large groups of people. As discussed previously, data from the atomic bomb survivors indicate a long latency period between the time of exposure and expression of the disease.

There is also the compounding factor that cancer is a generalization for a group of approximately 300 separate diseases, many being relatively rare and having different apparent causes. With low-dose study data, it is difficult to eliminate the possibility that some factor other than radiation may be causing an apparent increase in cancer induction. This difficulty is particularly apparent in studies of lung cancer, for example, where smoking is (a) such a common exposure, (b) poorly documented as to individual habits, and (c) by far the primary cause of lung cancer. Because cancer induction is statistical in nature, low-dose studies are limited by the fact that an apparent observed small increase in a cancer may be due to chance alone.

Despite the above-mentioned problems, and the lack of consistent or conclusive evidence from such studies to date, low-dose studies fulfill an important function. They are the only means available for eventually testing the validity of current risk estimates derived from data accumulated at higher doses and higher dose rates.

Low-dose groups that have been, and are currently being, studied include groups exposed as a result of medical procedures; exposed to fallout from nuclear weapons testing; living near nuclear installations; living in areas of high natural background radiation; and occupationally exposed to low doses of radiation. The National Academy of Sciences has reviewed a number of the low-dose studies in references 15 and 24. Their overall conclusion from reviewing these studies was:

> Studies of populations chronically exposed to low-level radiation, such as those residing in regions of elevated natural background radiation, have not shown consistent or conclusive evidence of an associated increase in the risk of cancer (reference 15).

This conclusion has been supported by studies that have been completed since reference 15 was published. For example, in 1990 the National Cancer Institute completed a study of cancer in U.S. populations living near 62 nuclear facilities that h been in operation prior to 1982. This study included commercial nuclear power plan and Department of Energy facilities that handle radioactive materials. The conclusio of the National Cancer Institute study was:

> There was no evidence to suggest that the occurrence of leukemia or any other form of cancer was generally higher in the (counties near the nuclear facilities) than in the (counties remote from nuclear facilities) (reference 26).

At the request of the Three Mile Island Public Health Fund, independent researcher investigated whether the pattern of cancer in the 10-mile area surrounding the Thre Mile Island (TMI) nuclear plant had changed after the TMI-2 accident in March 1979 and, if so, whether the change was related to radiation releases from the plant. A conclusion of this study was:

> For accident emissions, the authors failed to find definite effects of exposure on the cancer types and population subgroups thought to be most susceptible to radiation. No associations were seen for leukemia in adults or for childhood cancers as a group. (reference 27)

Of particular interest to workers at Naval Reactors' Department of Energy facilities studies of groups occupationally exposed to radiation. A 1990 survey of radiation

worker populations in the U.S. showed there were about 350,000 workers under study (reference 25). For more than a decade, Naval Reactors Program personnel have been among populations being studied. These studies are discussed below.

In 1978, Congress directed the National Institute for Occupational Safety and Health (NIOSH) to perform a study of workers at the Portsmouth Naval Shipyard. Congress also chartered an independent oversight committee of nine national experts to oversee the performance of the study in order to ensure technical adequacy and independence of the results. NIOSH concluded that "excesses of deaths due to malignant neoplasms and specifically due to neoplasms of the blood and blood-forming tissue, were not evident in civilian workers at Portsmouth Naval Shipyard" (reference 28). NIOSH did two followup studies focusing on leukemia and lung cancer and also concluded that radiation exposure at Portsmouth Naval Shipyard could not be shown to have contributed to the number of deaths from these causes (references 29 and 30).

In 1991, researchers from Johns Hopkins University, Baltimore, Maryland, completed a more comprehensive epidemiological study of the health of workers at the six Navy shipyards (including Portsmouth Naval Shipyard, discussed above) and two private shipyards that serviced the Navy's nuclear-powered ships (reference 31). This independent study evaluated a population of 70,730 civilian workers over a period fro 1957 (beginning with the first overhaul of the first nuclear-powered submarine, USS NAUTILUS) through 1981, to determine whether there was an excess risk of leukemia or other cancers associated with exposure to low levels of gamma radiation. This stu is of particular interest to workers at Naval Reactors' Department of Energy facilities because the type of radioactivity, level of exposure, and method of radiological contro at these shipyards are similar to Naval Reactors' Department of Energy facilities.

This study did not show any cancer risks linked to radiation exposure. Furthermore, tl overall death rate among radiation-exposed shipyard workers was actually less than t death rate for the general U.S. population. It is well recognized that many worker populations have lower mortality rates than the general population, because the workers must be healthy to perform their work. This study shows that the radiation-exposed shipyard population falls into this category.

The death rate for cancer and leukemia among the radiation-exposed workers was slightly lower than that for non-radiation-exposed workers and that for the general U.S population. However, an increased rate of mesothelioma, a type of respiratory syster cancer linked to asbestos exposure, was found in both radiation-exposed and non-radiation-exposed shipyard workers, although the number of cases was small (reflecti the rarity of this disease in the general population). The researchers suspect that shipyard worker exposure to asbestos in the early years of the Program, when the hazards associated with asbestos were not so well understood as they are today, mig account for this increase.

In conclusion, the Johns Hopkins study found no evidence to conclude that the health of people involved in work on U.S. nuclear-powered ships has been adversely affecte by exposure to low levels of radiation incidental to this work. The average annual radiation exposure from 1957 to 1981 for these shipyard workers is over 2½ times higher than the average annual exposure of 0.114 rem received by personnel assigne to Naval Reactors' Department of Energy facilities since 1958. Additional studies are planned to investigate the observations and update the shipyard study with data beyond 1981.

[redacted]

Numerical Estimates of Risk from Radiation

One of the major aims of the studies of exposed populations as discussed above is to develop numerical estimates of the risk of radiation exposure. These risk estimates are useful in addressing the question of how hazardous radiation exposure is, evaluating and setting radiation protection standards, and helping resolve claims for compensation by exposed individuals.

The development of numerical risk estimates has many uncertainties. As discussed above, excess cancers attributed to radiation exposure can only be observed in populations exposed to high doses and high-dose rates. However, the risk estimates are needed for use in evaluating exposures from low doses and low-dose rates. Therefore, the risk estimates derived from the high-dose studies must be extrapolated to low doses. This extrapolation introduces a major uncertainty. The shape of the curve used to perform this extrapolation becomes a matter of hypothesis (that is, assumption) rather than observation. The inability to observe the shape of this extrapolated curve is a major source of controversy over the appropriate risk estimate.

Scientific committees, such as the National Academy of Sciences-National Research Council Advisory Committee on the Biological Effects of Ionizing Radiations (reference 15), the United Nations Scientific Committee on the Effects of Atomic Radiation (reference 18), and the National Council on Radiation Protection and Measurements (reference 11) all conclude that accumulation of dose over weeks, or months, as opposed to in a single dose, is expected to reduce the risk appreciably. A dose rate effectiveness factor (DREF) is applied as a divisor to the risk estimates at high doses to permit extrapolation to low doses. The National Academy of Sciences (reference 15) suggested that a range of DREFs between 2 and 10 may be applicable and reported a best estimate of 4, based on studies of laboratory animals. The United Nations Scientific Committee on the Effects of Atomic Radiation (reference 18) suggested that a DREF of 2 or 3 would be reasonable based on available data. However, despite these conclusions by the scientific committees, some critics argue that the risk actually increases at low doses, while others argue that cancer induction is a threshold effect and the risk is zero below the threshold dose. As stated at the beginning of this section, the Naval Reactors Program has always conservatively assumed that radiation exposure, no matter how small, may involve some risk.

In 1972, both the United Nations Scientific Committee on the Effects of Atomic Radiation and the National Academy of Sciences-National Research Council Advisory Committee on the Biological Effects of Ionizing Radiations issued reports (references 32 and 33) that estimated numerical risks for specific types of cancer from radiation exposures to human beings. Since then, international and national scientific committees have been periodically re-evaluating and revising these numerical estimates based on the latest data. The most recent risk estimates are from the same two committees and are contained in their 1990 and 2000 reports, respectively (references 15 and 18). Both committees re-evaluated risk estimates based on the use of new models for projecting the risk, revised dose estimates for survivors of the Hiroshima and Nagasaki atomic bombs, and additional data on the cancer experience both by atomic bomb survivors and by persons exposed to radiation for medical purposes. A risk estimate for radiation-induced cancer derived from the most recent analyses, references 15 and 18, can be briefly summarized as follows:

> In a group of 10,000 workers in the U.S., a total of about 2,000 (20 percent) will normally die of cancer. If each of the 10,000 received over his or her career an additional 1 rem, then an estimated 4 additional cancer deaths (0.04 percent) might occur. Therefore, the average worker's lifetime risk of cancer has been increased nominally from 20 percent to 20.04 percent.

The above risk estimate was extrapolated from estimates applicable to high doses and dose rates using a DREF about 2. This estimate may overstate the true lifetime risk at

low doses and dose rates, because a DREF of 2 is at the low end of probable DREF values. The National Academy of Sciences (reference 15), in assessing the various sources of uncertainty, concluded that the true lifetime risk may be contained within an interval from zero to about six. The Academy points out that the lower limit of uncertainty extends to zero risk because “the possibility that there may be no risks from exposures comparable to external natural background radiation cannot be ruled out."

These statistics can be used to develop a risk estimate for personnel exposed to radiation associated with Naval Reactors' Department of Energy facilities. As stated previously, the average lifetime accumulated exposure for these personnel is about 1 rem. Therefore, based on the risk estimate presented above, the average worker's lifetime cancer risk at Naval Reactors' Department of Energy facilities may be statistically increased by about four one-hundredths of one percent, or from 20 percent for the general population to 20.04 percent for a worker at Naval Reactors' Department of Energy facilities.

Risk Comparisons

Table 6 compares calculated risks from occupational exposure at Naval Reactors' Department of Energy facilities to other occupational risks. This permits evaluation of the relative hazard of this risk versus risks normally accepted in the workplace. It should be kept in mind that the radiation risk is calculated based on risk estimates, whereas the other occupational risks are based on actual death statistics for the occupation.

TABLE 6

LIFETIME OCCUPATIONAL RISKS

Occupation (reference 11)	Lifetime Risk[1] Percent
Agriculture	2.1
Mining, Quarrying	2.0
Construction	1.5
Transportation and Public Utilities	1.0
All Industries Average	0.4
Government	0.4
Services	0.2
Manufacturing	0.2
Trade	0.2
Radiation exposure associated with Naval Reactors' Department of Energy facilities (risk estimate)	0.04

Further perspective on the lifetime risk from radiation exposure at Naval Reactors' Department of Energy facilities may be gained by comparison to other everyday risks as shown in Table 7.

1. Assumes a working lifetime of 47 years (age 18 to 65).

TABLE 7

SOME COMMONPLACE LIFETIME RISKS

Risk (reference 34 and 35)	Lifetime Risk[1] Percent
Smoking	9
Accidents (all)	2.6
Motor Vehicle Accidents	1.2
Falls	0.34
Accidental Poisoning	0.29
Suffocation	0.13
Drowning	0.11
Fires	0.10
Public Transportation	0.05
Radiation exposure associated with Naval Reactors' Department of Energy facilities (risk estimate)	0.04

Low-Level Radiation Controversy

A very effective way to cause undue concern about low-level radiation exposure is to claim that no one knows what the effects are. This has been repeated so often that it has almost become an article of faith that no one knows the effects of low-level radiation on humans. The critics are able to make this statement because, as discussed above, human studies of low-level radiation exposure cannot be conclusive as to whether or not an effect exists in the exposed groups, because of the extremely low incidence of an effect. Therefore, assumptions are needed regarding extrapolation from high-dose groups. The reason low-dose studies cannot be conclusive is that the risk, if it exists at these low levels, is too small to be seen in the presence of all the other risks of life.

The fact that a controversy exists is evidence that the radiation risk is small.

In summary, the effect of radiation exposures at occupational levels is extremely small. There are physical limits to how far scientists can go to ascertain precisely the size of this risk, but it is known to be small. Instead of proclaiming how little is known about low-level radiation, it is more appropriate to emphasize how much is known about the small actual effects.

Conclusions on the Effects of Radiation on Personnel

This perspective provides a better position to answer the question, "Is radiation safe?" If safe means zero effect, then the conclusion would have to be that radiation may be unsafe. But to be consistent, background radiation and medical radiation would also have to be considered unsafe. Or more simply, being alive is unsafe.

"Safe" is a relative term. Comparisons are necessary for actual meaning. For a worker, safe means the risk is small compared to other risks accepted in normal work activities.

1. Smoking and Motor Vehicle Accidents assume the population is at risk from age 18 to 76.5 (58.5 years). Other risks assume the population is at risk for a lifetime (76.5 years).

Aside from work, safe means the risk is small compared to the risks routinely accepted in life.

Each recommendation on limits for radiation exposure from the scientific and advisory organizations referenced herein has emphasized the need to minimize radiation exposure. Thus, the Naval Reactors Program is committed to keeping radiation exposure to personnel as low as reasonably achievable. Scientific and advisory organizations have not agreed on a radiation level below which there is no effect. Similarly, it is difficult to find a single human activity for which the risk can be confidently stated as zero. However, the above summaries show that the risk from radiation exposure associated with Naval Reactors' Department of Energy facilities is low compared to the risks normally accepted in industrial work and in daily life outside of work.

AUDITS AND REVIEWS

Checks and cross-checks, audits, and inspections of numerous kinds have been shown to be essential in maintaining high standards of radiological controls. First, all workers are specially trained in radiological controls as it relates to their own job. Second, written procedures exist that require verbatim compliance. Third, radiological controls technicians and their supervisors oversee radioactive work. Fourth, personnel independent of radiological controls technicians are responsible for processing personnel dosimeters and maintaining radiation exposure records.

Fifth, a strong independent audit program is required covering all radiological controls requirements. In all facilities this radiological audit group is independent of the radiological controls organization; the audit group's findings are reported regularly to senior management. This group performs continuing surveillance of radioactive work. It conducts in-depth audits of specific areas of radiological controls. This group checks all radiological controls requirements at least annually.

Sixth, the Department of Energy assigns to each facility a representative who reports to the Director, Naval Nuclear Propulsion, at Headquarters. One assistant to this representative is assigned full-time to audit and review radiological controls. Seventh, Naval Reactors Headquarters personnel conduct periodic inspections of radiological controls in each facility.

In addition, various aspects of the Naval Reactors Program have been reviewed by other Government agencies. For example, the General Accounting Office (GAO) performed a 14-month in-depth review of various aspects of Naval Reactors' Department of Energy facilities. In August 1991 (reference 36), the GAO published the following conclusions:

- We believe Naval Reactors Laboratories are accurately measuring, recording, and reporting radiation exposures.

- Naval Reactors reported exposures show that exposures have been minimal and overall are lower than commercial nuclear facilities and other Department of Energy facilities.

CLAIMS FOR RADIATION INJURY TO PERSONNEL

Personnel who believe they have received an occupational injury may file claims. The personnel who operate Naval Reactors' Department of Energy facilities are employees of corporations operating facilities under contract to the Department of Energy. These personnel file claims under State workmen's compensation laws. The claim may be handled through the contractor's insurance carrier or adjudicated by an administrative law judge. Either the employee or the contractor may appeal the judge's decision. In any case, the Naval Reactor's Program would support any claim for radiation injury where it could be technically and scientifically shown that the injury was more likely than not caused by the individual's occupational radiation exposure from the Program.

A case does not require a decision after filing unless it is actively pursued. A claim may lie dormant for many years theoretically to be pursued at a later date, whereupon a decision will be made. For the purpose of this report, claims that have had no activity in the last 5 years are counted as deferred.

There have been a total of five claims filed for injury from radiation associated with Naval Reactors' Department of Energy facilities. Of these claims, one was awarded and four have either been denied or deferred. The one case that was awarded occurred in 1955 and involved loss of hearing. A fine particle of radioactive material had entered the individual's ear canal and become lodged. The particle remained in the ear canal for approximately 9 days; as a result, the individual received a very high localized exposure to the ear drum. Following this incident, the individual suffered a 65 percent hearing loss in the affected ear. The claim was awarded in 1959.

Energy Employees Occupational Illness Compensation Program Act

In 2000, Congress passed the Energy Employees Occupational Illness Compensation Program Act (EEOICPA) to provide an alternative Federal compensation program for workers whose health was impacted as a result of nuclear weapons related work for Department of Energy contractors. The EEOICPA covers contractors and DOE employees, as designated by the Secretary of Energy, who worked in facilities that processed or produced radioactive material for use in the production of atomic weapons. The current list of covered facilities can be found in the Federal Register, Volume 67, Number 249, page 79068, dated December 27, 2002.

Because of the effectiveness of Naval Reactors' worker protection, worker training, and workplace monitoring programs, employees who performed Naval Reactors' related work at Naval Reactors' Department of Energy facilities were not included in the EEOICPA. As discussed earlier, the GAO reported to Congress in 1991 that "Naval Reactors Laboratories are accurately measuring, recording, and reporting radiation exposures," and "exposures have been minimal and overall are lower than commercial nuclear facilities and other Department of Energy facilities." This longstanding record of effectiveness in worker protection, worker training, and workplace monitoring supports the conclusion by Congress that workers at Naval Reactors' Department of Energy facilities did not need the compensation alternatives created for workers in the nuclear weapons complex by the EEOICPA.

Some personnel who were employed at Naval Reactors' Department of Energy facilities during certain periods are covered by the EEOICPA because those facilities performed nuclear weapons work unrelated to the Naval Reactors program. These facilities include the Separations Process Research Unit at the Knolls Atomic Power Laboratory, the Peek Street Facility in Schenectady, New York, the Sacandaga Facility in Glenville, New York, and the decommissioning work of the Shippingport Atomic Power Station. Each of these facilities is discussed in more detail below.

The Separations Process Research Unit at the Knolls Atomic Power Laboratory involved laboratory scale testing of radionuclide separation processes eventually used in production processes at the Atomic Energy Commission's Hanford Site in Washington and at the Savannah River Plant in South Carolina. This work began in the 1940's and was initially conducted under the direction of the Atomic Energy Commission. Following completion of this research in 1953, remediation of related work areas and waste products began; most of the clean up work was completed by 1965. Areas requiring additional remediation have been maintained in protective layup pending final remediation. In March 1965, the radiological controls previously used for this work under the Atomic Energy Commission were supplanted by controls specifically approved by Naval Reactors. Therefore, work after March 1965 to maintain Separation Process Research Unit facilities in protective layup were under the authority of Naval Reactors and outside the scope of the EEOICPA.

In the late 1940s and early 1950s, the General Electric Company operated two Federal Government facilities in support of developmental programs for the Atomic Energy Commission. These two facilities were the Peek Street Facility and the Sacandaga Facility. Though these sites were decontaminated, decommissioned, and sold to private parties in the mid-1950s, these sites were re-surveyed between 1988 and 1991 by Naval Reactors to ensure compliance with current Department of Energy guidelines. Based on those surveys, additional minor remediation was completed by Naval Reactors in 1994. Therefore, work at the Peek Street Facility and the Sacandaga Facility in the 1980s and 1990s was under the regulatory oversight of Naval Reactors and is outside the scope of the EEOICPA.

As discussed elsewhere in this report, Naval Reactors was responsible for regulatory oversight throughout the construction and operation of the Shippingport Atomic Power Station. When operation of the station ended and defueling was completed in September 1984, Naval Reactors transferred oversight responsibility for the station to the Department of Energy Office of Terminal Waste Disposal and Remedial Action. Therefore, work at the Shippingport Atomic Power Station before September 1984 is outside the scope of the EEOICPA.

Naval Reactors and its contractors maintain custody of employment and radiation exposure records for personnel who worked at the Peek Street Facility, the Sacandaga Facility, and the Separation Process Research Unit. When requested by the DOE or the National Industrial Occupational Safety and Health (NIOSH) division of the Department of Health and Human Services, Naval Reactors provides employment verification and radiation exposure information in accordance with the procedures required by the EEOICPA.

As defined in the EEOICPA, the Department of Labor determines the eligibility of personnel filing a compensation claim; and if needed, NIOSH performs a radiation dose reconstruction to support a determination of causation and ultimate award or denial of benefits. Through December 2002, Naval Reactors has provided dose information to NIOSH for eight claims for personnel whose employment included non-Naval Nuclear Propulsion Program work at covered facilities now under Naval Reactors cognizance.

ABNORMAL OCCURRENCES

It is a fact of human nature that people make mistakes. The key to a good radiological controls program is to find the mistakes while they are small and prevent the combinations of mistakes that lead to more serious consequences. The preceding section on inspections supports the conclusion that the Naval Reactors Program gives more attention to errors and their prevention than to any other single subject. Requiring constant focus on improving performance of radiological work has proven effective in reducing errors.

In addition, radiological controls technicians are authorized and required to stop anyone performing work in a manner that could lead to radiological deficiencies. One definition of "deficiency" is a failure to follow a written procedure verbatim. However, the broadest interpretation of the term "deficiency" is used in Naval Reactors' Department of Energy facilities' radiological controls program. Anything involved with radiation or radioactivity that could have been done better is also considered a radiological deficiency. All radiological deficiencies receive management attention.

There is a higher level of deficiency defined as a radiological incident. Incidents receive further management review, including evaluation by senior personnel at Naval Reactors Headquarters and review by the Director, Naval Nuclear Propulsion. Improvement programs over the years have consistently aimed at reducing the number of radiological incidents. As improvements occurred, the definition of what constitutes a Naval Reactors incident was changed to define smaller and smaller deficiencies as incidents. These changes were made so that the incident reporting system would continue to play a key role in upgrading radiological controls. As a result, it is not practicable to measure performance over time merely by counting numbers of radiological incidents or deficiencies.

The Department of Energy and its predecessors have used a separate reporting system that has been nearly constant over time and therefore can be used as a basis for comparison. This system defines a Type A radiation exposure occurrence as an event that causes an individual's external radiation exposure to equal or exceed 25 rem (reference 37). The Nuclear Regulatory Commission uses similar criteria to define a radiation-related abnormal occurrence; abnormal occurrences are included in the NRC's quarterly report to Congress. Naval Reactors regularly evaluates radiological events using these criteria for comparison.

Since the beginning of operations at Naval Reactors' Department of Energy facilities, there has not been a single radiation incident that met the criteria of a Type A or abnormal occurrence.

The policy of the Naval Reactors Program is to provide for close cooperation and effective communication with State radiological officials involving occurrences that might cause concern because of radiological effects associated with Program facilities. The Naval Reactors Program has reviewed radiological matters with State radiological officials in the States where Naval Reactors' Department of Energy facilities operate. Although there has never been an abnormal occurrence that has resulted in radiological effects to the public outside these facilities or that resulted in radiological injury to residents of the States working inside these facilities, States were notified when inquiries showed public interest in the possibility such events had occurred.

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REPORT NT-03-4
MARCH 2003

OCCUPATIONAL SAFETY, HEALTH, AND OCCUPATIONAL MEDICINE REPORT

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WASHINGTON, D.C. 20585

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OCCUPATIONAL SAFETY, HEALTH, AND OCCUPATIONAL MEDICINE REPORT

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TABLE OF CONTENTS

LIST OF FIGURES

SUMMARY

The Naval Reactors Program is a joint Department of Energy (DOE)/Department of the Navy Program with central control by a single headquarters organization. The Program is responsible for two DOE laboratories, one DOE site with two prototype naval nuclear propulsion plants, one DOE site which operates the Expended Core Facility (for examination and dispositioning of naval fuel and irradiation tests), and one naval training facility with two moored training ships.

The Naval Reactors Program faces the unique challenge of coherently integrating and managing DOE testing and Navy training responsibilities, DOE and Navy facilities, civilian and military personnel, and DOE and Navy health and safety standards. Successful integration requires special technical knowledge and experience in selecting and implementing standards that ensure the safe training of Navy personnel in an environment as realistic as possible.

The same principles of personal responsibility, technical knowledge, rigorous training, and auditing that have been applied to achieve the Naval Reactors Program's strong nuclear safety record are applied to Occupational Safety, Health, and Occupa tional Medicine (OSHOM) programs. A multi-tier approach incorporating safety, in all levels of work, is used throughout the Program. Primary responsibility for employee safety and health resides with operations management and the workers themselves, with assistance and oversight from industrial hygiene, safety, and medical professionals. Workers undergo safety and health training, and they work to written requirements. Inspection, oversight, and feedback systems are designed to provide continual improvement.

This annual report describes the non-radiological aspects of OSHOM programs at Naval Reactors' DOE laboratories and prototype training facilities and the Moored Training Ship facility. Included in this report are performance indicators that measure the effectiveness of OSHOM programs. Performance indicators, such as injury and illness incidence rate, restricted workday case rate, and days away from work case rate, are provided for a 5-year period through 2002 in Figures 1 through 4. When these indicators are compared for the Naval Reactors Program, DOE, and general industry, it can be seen that the Program has maintained rates significantly less than the incidence rates of general industry in all categories and is generally below overall DOE incidence rates.

A 14-month comprehensive assessment of the Program's environmental, safety, and health practices was conducted by the General Accounting Office (GAO) in 1990-1991. The GAO reported that there were no significant deficiencies. Such a finding is independent evidence that the Naval Reactors Program is providing a safe and healthy workplace while meeting the challenges of integrating civilian and military standards in a unique research and training environment.

NAVAL REACTORS PROGRAM BACKGROUND, MISSION, AND FACILITIES

Background

The Naval Reactors Program (hereafter referred to as "the Program") is comprised of military personnel and civilians who design, build, operate, maintain, and oversee operation of naval nuclear-powered ships and associated support facilities. The Program has a broad reach, maintaining responsibility for nuclear propulsion matters from cradle to grave. Program responsibilities are delineated in Presidential Executive Order 12344 of February 1, 1982, and Public Law 106-65 of October 5, 1999 (50 U.S.C. §2406). These responsibilities encompass:

- The Navy's nuclear-powered warships.
- Two research and development laboratories.
- Contractors responsible for the design, procurement, and construction of propulsion plant equipment.
- Shipyards that construct, overhaul, and service the propulsion plants of nuclear-powered vessels.
- Navy support facilities and tenders.
- Nuclear power schools and Naval Reactors training facilities.
- The Naval Nuclear Propulsion Program Headquarters organization and field offices.

The Government-owned/contractor-operated Bettis and Knolls Atomic Power Laboratories are research and development laboratories devoted solely to naval nuclear propulsion work. With combined staffs of approximately 5,700 engineers, scientists, technicians, and support personnel, their mission is to develop advanced naval nuclear propulsion technology and to provide technical support for the continued safe, reliable operation of all existing naval reactors.

The Bettis Atomic Power Laboratory operates the Expended Core Facility at the Naval Reactors Facility in Idaho. At the Expended Core Facility, naval spent nuclear fuel from nuclear-powered warships and the Program's prototypes is examined for evidence of any unusual conditions such as unexpected corrosion, unexpected wear, or structural defects. The examinations provide data on current reactor performance, validate models used to predict future performance, and support research to improve reactor design. Following examination, this facility also prepares naval spent nuclear fuel for storage and disposal.

The Knolls Atomic Power Laboratory operates land-based prototype nuclear propulsion plants in New York. Prototype facilities provide platforms for the operational testing of new designs and promising new technologies under typical operating conditions before introduction into the Fleet. The prototype facilities also support the unique training

requirements of the Program and are staffed by highly qualified instructors. These facilities provide for hands-on training so that, before their first sea tour, all operators have qualified on an operating nuclear reactor.

The Knolls and Bettis laboratories are also responsible for shutdown prototype nuclear propulsion plants in New York and Idaho, which are in various stages of inactivation and dismantlement.

To augment its hands-on training resources, the Program established the Moored Training Ship facility at the Naval Weapons Station in Charleston, South Carolina, in 1990. Two nuclear-powered submarines, which have been decommissioned and converted for training, are moored at the facility. Navy personnel operate the facility with the assistance of a technical staff from Bettis Atomic Power Laboratory.

Scope of Report

The Program is solely responsible for OSHOM matters at its DOE laboratories and prototype facilities, which are operated exclusively for the Program. Within the Navy Occupational Safety and Health (NAVOSH) Program, the Naval Reactors Program is responsible for OSHOM matters at the Moored Training Ship facility. Non-radiological OSHOM matters at other Navy facilities (e.g., shipyards or support facilities) are the primary responsibility of other Navy organizations (although the Program often works with these organizations on OSHOM matters that could affect naval nuclear propulsion plant operations). Therefore, this report focuses on the OSHOM programs at Program laboratories and their associated prototype training facilities and the Moored Training Ship facility.

As stated in the summary, this report covers non-radiological OSHOM programs at Program facilities. The Program is also responsible for radiological health and safety at all Program DOE and Navy facilities and ships where naval nuclear propulsion work is performed. Radiological safety and health information for the Program is described in detail in two other publicly available reports (references 1 and 2).

This report covers calendar year 2002. Occupational safety and health data for calendar years 1998 through 2002 are included to allow comparison to Program performance in recent years.

Past Operations

Safety, Industrial Hygiene, and Occupational Medicine programs were developed and implemented in the earliest years of the Program in the form of documented principles, practices, procedures, and facility safety manuals. The Atomic Energy Act of 1954 assigned to the Atomic Energy Commission (AEC), the predecessor to the DOE, responsibility for regulation of activities conducted pursuant to the Act to protect safety and health. Basic requirements were promulgated by the AEC Manual, part 0500 (Health and Safety), which established standards applicable to all AEC contractor operations. OSHOM programs were staffed with individuals dedicated to these functions.

Since passage of the Williams-Steiger Occupational Safety and Health Act of 1970 (OSH Act), the national standard of care for occupational safety and health has improved. Under the OSH Act, the Program retained authority for OSHOM programs of its contractors and has mandated proactive programs and practices at least as stringent as those required by the Occupational Safety and Health Administration for commercial facilities. The various contractor safety, industrial hygiene, and medical programs have been dynamic and have experienced substantial growth since their inception as new requirements have developed.

Militarily Unique Mission and Facilities

As previously stated, a major responsibility of the Program is to train naval personnel to operate naval nuclear propulsion plants. At the Moored Training Ship facility, this training is conducted aboard specially modified, moored nuclear-powered submarines that have been decommissioned and converted for training. At one Program DOE facility, training of naval personnel is conducted in land-based prototype naval nuclear propulsion plants, which are representative of the engineering spaces aboard naval nuclear-powered warships. Navy and contractor personnel, who meet the same qualification standards as naval personnel, conduct the training.

Procedures used by the Program to operate the nuclear reactors and associated systems in the land-based prototype propulsion plants are identical to those used in warships. This includes the use of the same Navy shipboard occupational safety and health requirements as those applied in the Fleet. The Navy safety and health requirements are tailored to meet the militarily unique aspects of the "sea services" and combat roles of warships. Training naval personnel in settings and operations identical to those encountered at sea is a fundamental tenet of the Program that directly contributes to the safe operation of naval shipboard reactors.

In implementing the OSH Act, Executive Order 12196 and 29 CFR 1960 recognized the unique equipment and operations used by the military and exempted militarily unique equipment and operations from coverage by OSH Act regulations. Heat stress, lock-out/tag-out procedures, and structural safety requirements (e.g., hand rails) are examples of areas where civilian OSHOM requirements must be reconciled with the configuration and operational requirements of militarily unique equipment. For such equipment and operations, the Department of Defense occupational safety and health programs ensure that military personnel are protected.

POLICY AND IMPLEMENTATION

Naval Reactors Program Policy

It is the policy of the Program to eliminate or control workplace hazards at Program facilities such that all employees are provided with a safe and healthful workplace.

OSHOM Program Elements

The control of hazards is accomplished through technical and managerial techniques that are recognized as industry standards. These techniques include:

- Establishment of responsibilities: All levels of management and supervision are assigned accountability for the safety and health of their workers and peers.

- Qualified Professional Staffing: The OSHOM programs at Program facilities include certified professionals in the disciplines of Occupational Safety, Industrial Hygiene, and Occupational Medicine. In addition, numerous other site personnel are assigned collateral OSHOM duties, such as workplace safety monitors.

- OSHOM Training of Management and Workers: Facility management, supervisors, and employees receive training that addresses policies and procedures, physical and chemical hazard recognition, control strategies and requirements, emergency procedures, and employee information/concern resolution processes.

- Planning: Work plans and specifications are reviewed by facility OSHOM professionals to identify and eliminate or mitigate hazards.

- Emergency Planning: Emergency procedures are well documented. Emergency responders and supervisors must pass initial qualifications and routinely perform drills to maintain and improve their response skills. Trained personnel are available around the clock to respond to emergency situations and provide first-aid capability.

- Extension of OSHOM Program to Subcontractor Employees: Subcontractors performing work at Program facilities are required by contract to work to safety and health requirements as stringent as those implemented for Program facility employees. Subcontractor compliance with safety and health requirements is overseen by facility personnel.

- Written Requirements: Employees work to written requirements, such as manuals and procedures, which incorporate safety and health requirements.

- Routine, Independent OSHOM Evaluation: Naval Reactors Headquarters and field office personnel, as well as dedicated auditors within the facility's organization, provide independent evaluation of OSHOM Programs. Assessments are detailed, formal, and documented; corrective actions are tracked to closure.

Hazard Assessment Systems

Methods of assessing hazards include:

- Baseline safety and industrial hygiene surveys.
- Routine self-inspection and self-appraisal programs.
- Hazard analysis, which evaluates potential hazards associated with certain job categories or specific tasks.
- Industrial hygiene monitoring programs that use state-of-the-art equipment and independent laboratory analysis in accordance with nationally recognized procedures.
- Accident investigation systems, which ensure timely review, provide written reports, and ensure responsive actions are tracked to closure.
- Preventive maintenance programs that ensure safety systems function as designed.

Worker Participation

Workers participate in various committees, internal programs, and site audits and inspections. Employees are encouraged to report their concerns to management or OSHOM staff or formally document them via an employee concern management system (reference 3). Employee/management communications include follow up and tracking of identified employee concerns and of issues identified during inspections, audits, or committee meetings.

OSHOM REQUIREMENTS

Naval Reactors Program Authority and Responsibility for Occupational Safety and Health

Under the Atomic Energy Act of 1954, the DOE is assigned authority to set and enforce occupational safety and health standards for facilities and activities covered by the Act. Within the DOE, authority to set and enforce these standards at Program facilities is assigned to the Deputy Administrator for Naval Reactors, pursuant to Executive Order 12344, Public Law 106-65 (reference 4), and 42 U.S.C. §7158. These documents establish that the director of the Program is responsible for all matters pertaining to naval nuclear propulsion. The Program establishes and enforces OSHOM requirements at Naval Reactors DOE facilities independent of other DOE organizations (e.g., nuclear fuel and weapons production operations). This ensures that OSHOM standards support the militarily unique training mission (discussed earlier) and that they are consistently applied and technically sound.

For nearly all other civilian workplaces, the Occupational Safety and Health Act of 1970 provides authority to set occupational safety and health standards. The OSH Act excludes from its scope activities that are regulated under separate statutory authority, such as the Atomic Energy Act discussed above. For Federal workplaces, each Federal agency (e.g., Department of the Navy) is responsible under the OSH Act for establishing and maintaining an effective and comprehensive occupational safety and health program consistent with the OSH Act. The Navy program and standards are documented in OPNAV Instruction 5100.23 (reference 5). Consistent with Executive Order 12344, the Program enforces the implementation of these requirements, as well [redacted]

Implementation of DOE Directives and Navy Occupational Safety and Health Program Requirements

The Naval Reactors Program uses DOE directives to set the standards for its DOE facilities. Since DOE directives are focused on non-military activities, some of the requirements may not be directly applicable to Program activities. Such requirements are modified by the Program as necessary to integrate the requirements with militarily unique systems and operations, in order to prevent conflicts with Navy training requirements and to maintain the prototypes' ship-like environment.

Because the Moored Training Ships are naval facilities, Navy occupational safety and health requirements are applied (references 5 and 6).

Occupational Medical Program Requirements

The Program occupational medical requirements for contractor and Federal employees [redacted]

PERSONNEL

Contractor Health and Safety Council

The Program maintains a Contractor Health and Safety Council, whose membership includes senior safety and health professionals from each Program facility. The purposes of the Council are (1) to provide a forum in which experiences and information can be exchanged, and new safety and health initiatives can be identified and quickly implemented, and (2) to maintain the HSSRD. These functions are accomplished by regular conferences (at least monthly) of the Contractor Health and Safety Council. In addition, the Council meets annually with Program Headquarters personnel to review performance and establish objectives for the coming year.

Professional Staffing

Adequate professional staffing is assigned to OSHOM programs to ensure a safe and healthful workplace at all Program facilities. All key professional occupational safety and health staff personnel satisfy, at a minimum, the requirements contained in the Office of Personnel Management standards for Safety and Occupational Health Manager, Safety Engineer, or Industrial Hygienist. Each Program activity is staffed by, or has contractual arrangements with, one or more physicians who are board-certified in or experienced in occupational medicine.

The Program's occupational safety and health personnel are qualified by their academic backgrounds and experience to perform workplace evaluations, technical monitoring, testing, consulting, and other essential functions of their professions. Involvement with professional organizations is supported, and facility staff hold memberships in all major safety and industrial hygiene professional societies.

Professional staff hold certifications from the American Board of Industrial Hygiene and/or the Board of Certified Safety Professionals. These certified professionals demonstrate, by passing rigorous examinations, that they are specially trained, knowledgeable, and competent in industrial hygiene and/or safety.

The capabilities of all professional staff members are enhanced by attendance at professional technical society meetings, participation in continuing education programs at universities and other recognized training centers, and involvement with internal education and training programs developed by individual Program sites. These activities are designed to improve the safety and health professional's ability to anticipate and recognize potential workplace hazards; measure, analyze, and evaluate occupational safety and health trends; and define and implement effective controls.

OSHOM managers are experienced individuals with extensive education and rigorous training that give them special qualifications to manage these programs. Although these managers report to the site manager (commanding officer at the Moored Training Ship facility), their oversight role remains independent from production concerns.

The occupational safety and health professionals at Program facilities monitor the workplace, evaluate workplace hazards, implement appropriate controls, review work

procedures for proper safety controls, analyze safety and health performance indicators, and maintain appropriate records. In general, however, the safety and health staff is not directly involved in site operations unless specific safety issues arise. In such cases, the safety and health staff work with the facility operations staff and Navy personnel to resolve the issue.

Operations Personnel

First-level operations supervisors, such as work-area managers and supervisors, are given primary responsibility for the safety and health of their subordinates. Operations personnel implement standards and procedures developed by the facility safety and health professional staff. Operations personnel are provided general and job-specific safety training to enable them to identify safety hazards and unsafe work practices.

Upper-level operations management staff at Program facilities are also responsible for the safety and health of their personnel. They reinforce the importance of safety and health requirements by establishing applicable policies and objectives and assigning appropriate responsibility and authority to all levels of management and supervision.

Each operating facility also maintains a Safety Representative program, in which an individual from a work area (such as a department) serves as a safety representative. The safety representatives are given additional training, attend periodic meetings, and are tasked with monitoring their work area to identify any hazards or unsafe work practices to facility OSHOM personnel.

Naval Reactors Field Office Representatives

All Program facilities have a co-located Naval Reactors field office. The field office is staffed with Naval Reactors personnel who report directly to Headquarters and whose function is to ensure contractor compliance with Program requirements. The field office representatives provide independent oversight of facility operations and allow Naval Reactors Headquarters to maintain close surveillance of events occurring at the facilities. Each field office has personnel with specific responsibilities in OSHOM matters to effectively oversee facility OSHOM programs.

Navy Personnel Assigned to Naval Reactors DOE Facilities

Active-duty Navy personnel are assigned to Naval Reactors DOE prototype sites to conduct and receive training in the operation of naval nuclear propulsion plants. The safety and health of these personnel is the overall responsibility of the Commanding Officer, Nuclear Power Training Unit (located on site). Each prototype plant has safety representatives who are responsible for ensuring that safety and health requirements are implemented and followed. The safety representatives have access to, and work with, the professional safety and health staff at the facility to resolve any OSHOM issues.

The commanding officer also maintains a liaison with a nearby Naval Branch Medical Clinic, which provides occupational medical support services to Navy personnel. The

facility OSHOM personnel work with the affiliated Naval Branch Medical Clinic to ensure the safety and health of Navy personnel.

Emergency Response Capability

Each Program facility has emergency response capabilities for significant events. At each site, trained and qualified individuals are assigned to respond to the scene of any emergency that may occur, evaluate the circumstances, and initiate appropriate corrective actions. When necessary, a separate site emergency control center is manned with specially trained personnel to handle a variety of emergencies.

Individuals are assigned to site emergency response teams on the basis of their expertise and experience. Emergency responders frequently train and drill to improve their skills and maintain their qualifications. Major drills involving the entire site emergency response team are conducted periodically; smaller scale drills involving limited participation are conducted more frequently.

Each operating facility has qualified emergency medical personnel to provide emergency medical care. Most sites are also staffed with one or more medical doctors during day shifts. Additional groups of individuals (e.g., emergency medical technicians) are specifically trained and assigned to provide medical assistance. Each site has arrangements with a local hospital to provide emergency medical care beyond the capabilities of facility medical personnel.

HAZARD IDENTIFICATION AND ANALYSIS

Regulations, Requirements, and Technical Information

To maintain a current level of knowledge and expertise in this area, members of the occupational safety and health staff:

- Review the Federal Register and subscribe to review services to identify and determine the applicability of new or proposed regulations to Program facilities. The results of these reviews are provided to OSHOM and operations personnel.

- Review and incorporate applicable safety and health requirements and lessons learned into site procedures. Such requirements and lessons learned are found in DOE and Navy safety and health bulletins and other relevant documents.

- Maintain professional certification in the fields of safety, industrial hygiene, or occupational health.

- Participate in professional societies (e.g., the American Industrial Hygiene Association, American Society of Safety Engineers, American College of Occupational and Environmental Health, and the American Association of Occupational Health Nurses) that provide information via publication of professional journals, national conferences, seminars, and society meetings.

- Discuss and resolve safety and health issues in the Naval Reactors Program Contractor Health and Safety Council conferences.

Project Evaluation

Facility projects involving work that could affect the safety and health of personnel are reviewed and evaluated by the respective facility safety and health organizations. These evaluations typically involve review of the work project from initial concept through the development of detailed work procedures or construction plans and technical specifications. One of the primary functions of this conceptual review is to identify alternate methods or materials that can be employed to eliminate or reduce the hazards associated with the project under review. Safety and health personnel must signify that applicable safety and health practices are integrated into written work procedures and must ensure that all applicable fire and life safety code requirements are satisfied.

The qualifications and work practices of subcontractors to perform specific facility project work are evaluated by safety and health personnel to ensure that subcontractor work meets the standards of the Program. The safety and health standards that subcontractors must use are incorporated directly into the contractual requirements set forth in requests for proposals and purchase orders.

Procurement Reviews

Each Program facility has a formal system to evaluate equipment and chemicals proposed for purchase to minimize or eliminate safety and health hazards. This system includes approval by safety and health organizations of requests for materials or new equipment. Material Safety Data Sheets (MSDSs) for all products or materials proposed for use are reviewed by the facility's safety and health organization before their initial use. This allows facility safety and health personnel to identify potential hazards and specify proper protective measures to reduce these hazards.

Hazard Analysis

Hazard analyses, such as job safety analyses or task analyses, are processes used throughout the Program to review work practices and identify concerns associated with overall work procedures.

Various job categories or facets of complex jobs are evaluated to identify potential hazards. Once potential hazards are identified, actions are taken to minimize the hazard and communicate appropriate precautions. Cognizant supervisors are responsible for ensuring that hazards are addressed and that corresponding tasks, equipment, or material changes are implemented. Safety and health professionals may help supervisors prepare an analysis, and in all cases shall review the hazard analysis for accuracy and completeness.

Hazard analyses are used in training individual employees, preparing for planned safety observations, reviewing job procedures, and studying the job for improvements in safety and health methods. Whenever a significant safety or health issue arises, further analyses are conducted; procedures may be altered to incorporate the lessons learned.

Pertinent information is forwarded to the occupational medical department for use in evaluating the workplace environment and/or hazards applicable to each employee.

Industrial Hygiene and Medical Workplace Hazard Evaluations

The basic elements of industrial hygiene and occupational medical workplace hazard evaluations at Program facilities include:

- Use of appropriate exposure limits established by the Navy Occupational Safety and Health (NAVOSH) program, Occupational Safety and Health Administration (OSHA), and American Conference of Governmental Industrial Hygienists (ACGIH) (references 5, 6, 9, and 10). In this regard, the Program continues to use OSHA limits established in 1989 despite a 1992 court decision, which vacated these more protective exposure limits.

- Regular worksite assessments by industrial hygiene and medical staff for the purpose of evaluating potential health hazards.

- Documented review of materials, processes, work practices, and procedures used on specific jobs to determine hazard exposure potentials. These reviews

determine specific job tasks that warrant routine or non-routine exposure monitoring, the use of personal protective equipment, or development of standardized work procedures to characterize and mitigate exposure to potential hazards.

- Establishment of workplace exposure monitoring programs which characterize potential hazard exposures during normal job activities throughout the facilities. Exposures are determined using standard exposure monitoring protocols as defined by the National Institute of Occupational Safety and Health (reference 11) and other recognized formats.

- Submission of validated exposure data to the occupational medical staff for evaluation and incorporation into DOE facility personnel medical records. For Navy personnel, relevant exposure data are sent to the Naval Branch Medical Clinic for inclusion in personnel medical records.

- Feedback to supervisory and management personnel on the results of employee exposure evaluations and monitoring so that procedural adjustments can be made if required.

- Medical examinations of personnel, based on potential exposures determined by the processes noted above.

Trend Analysis

Injury/illness documentation, medical records, and other records are reviewed frequently to ensure problem areas are identified and corrective actions are appropriate. At Program DOE facilities, injury and illness data for civilian personnel and subcontractors are compiled quarterly and submitted to the DOE. Accident reports for naval personnel at DOE facilities and at the Moored Training Ship are submitted to the Navy in accordance with NAVOSH requirements (references 5 and 6).

Analyzing trends is one of the most effective ways to identify problem areas and institute appropriate corrective measures to reduce accidents. Evaluations of each reportable occurrence are factored into continual trend analysis by process/operation, type of injury/illness, or any other categorization needed to focus improvement actions at the root causes. In addition, workers compensation records and medical clinic records provide supplemental accident history, which may be used in reviewing injuries and illnesses. Following review, corrective actions (such as procedure revision, evaluation of work practices, additional training, and/or hazard analysis updating) are taken. Program facilities analyze even minor injury/illness events so that improvements may be implemented to prevent more serious injuries from occurring.

Critiques and Event Reporting

The Program evaluates and/or critiques significant events that caused or could potentially have caused injury to personnel. Critiques are formal evaluations of an event conducted by qualified individuals at each facility with Naval Reactors field office personnel in attendance. Facts pertinent to the event are documented, corrective actions established, and minutes are issued. For more serious events, and for events that have Program-wide significance, formal reports are issued and reviewed by Naval Reactors Headquarters.

The Contractor Health and Safety Council conducts frequent teleconferences so that facilities may discuss health and safety events and lessons learned from those events.

HAZARD CONTROL

OSHOM Manuals

All Naval Reactors Program facilities have written procedures defining programs to control potential safety and health hazards. These procedures are compiled into each individual facility's safety, industrial hygiene, and occupational medicine manuals. Operations personnel prepare detailed written operating procedures and maintenance/repair manuals that incorporate safety and health procedures from these OSHOM manuals.

New Employee Indoctrination

Program facilities provide all new employees with occupational safety and health indoctrination. This training includes facility safety instructions, procedures for reporting injuries and concerns, employee responsibilities, personal protective equipment, introduction to the facility's OSHOM program, and an overview of various facility emergency procedures.

Hazard Communication and Awareness Training

Hazard communication programs train workers to recognize workplace hazards through chemical labeling, manufacturer's material safety data sheets, and discussions of hazards associated with certain job tasks or work areas. Hazard communication programs also train workers in the appropriate protective measures needed to minimize exposure to identified hazards.

In addition to hazard recognition training, awareness training is conducted to sensitize workers to look for and correct unsafe practices that could result in injury. Awareness training emphasizes and reinforces the concept that safe behavior will significantly reduce the chance of personal injury.

Continuing Training Programs

Training on OSHOM programs, as well as on many other aspects of each employee's job assignment, is regularly conducted at Program facilities. Continuing training provides knowledge on new requirements and ensures necessary skills and qualifications are maintained.

Navy Student and Instructor Training

Navy students and their instructors make up a large portion of the Program population at prototype sites and the majority of the population at the Moored Training Ship facility in Charleston. The rigorous training and qualification program for all naval nuclear propulsion plant operators includes key shipboard occupational safety and health requirements such as electrical safety, chemical use, gas-free engineering, emergency response actions, use of protective equipment, lock-out/tag-out, and other related safety requirements.

Informational Bulletins

Informational Bulletins (including DOE and Navy newsletters, training course schedules, defective materials notifications, and other sources of OSHOM news) are distributed to Contractor Health and Safety Council members and the Naval Reactors field offices. This information enables each facility to remain up to date with the latest OSHOM developments and to pass this information on to facility personnel. Each facility subscribes to a number of OSHOM publications.

Safety Representatives/Observers

Each Program facility has a safety representative or observer program. Safety representatives come from major departments and perform work area surveillances and submit written reports to work area management for improvement actions. These representatives also act as a conduit for other employees to express concerns. Employee suggestions are actively solicited, evaluated, and, if appropriate, implemented. Representatives meet regularly to receive training, discuss concerns, and provide the OSHOM staff and operations management with recommendations for improvements to facility OSHOM programs.

Concern Reporting

All Naval Reactors facilities have a civilian employee concerns management program in place (reference 3). Employee concerns programs enable employees to raise safety and health concerns to the attention of management or occupational safety and health departments for corrective actions. Under these programs, employees may choose to anonymously report concerns. If the employee chooses not to report anonymously, the employee is informed of the status of corrective actions associated with the concern.

If an employee is not satisfied with the problem resolution, the concern will proceed to the next higher level of management. In the event that the employee is not satisfied with the resolution from the facility management chain, a procedure is in place to file concerns directly with Naval Reactors field office representatives. Employees may also bypass the management chain and file concerns directly with DOE.

Navy personnel concerns are handled within the military chain of command (references 5 and 6).

Tracking and Follow-up Systems

All Program facilities have a systematic process for ensuring the timely resolution of safety and health issues. Safety and health hazards are corrected immediately, if possible, or stabilized to minimize associated hazards and then formally documented for tracking until final resolution. Open issues are tracked by prioritizing them on the basis of the hazard severity, and appropriate time limits are assigned to complete corrective actions, to ensure that all issues are resolved promptly.

Subcontractor Performance at Program Facilities

Each Program facility has procedures established for ongoing oversight of subcontractor work, including bidding and specification requirements. Subcontractors performing work at Program facilities are required by contract to comply with the same safety and health standards normally invoked at those facilities.

A multi-year subcontract has been placed with Electric Boat Corporation to complete prototype inactivation work at the Knolls Atomic Power Laboratory prototype site in New York. This subcontractor has extensive experience in the construction and servicing of naval nuclear-powered vessels. In addition to the oversight provided by the prime contractor responsible for site operations, this subcontractor employs full-time, on-site safety and health professionals who implement OSHOM programs for their work analogous to those instituted by the primary contractor. Additional subcontractors are also used at Program sites to complete construction projects and perform maintenance work that exceeds the capabilities of in-house work forces.

All subcontractors at Program facilities are responsible for the safety and health of their employees and their subcontractors, and for taking corrective action on safety and health deficiencies resulting from their operations.

Subcontractor Worksite Overview

Subcontractors performing work at Program facilities are responsible for indoctrinating their personnel on all safety and health requirements, and any job-specific requirements. The facility safety and health organization may assist in these indoctrinations. All subcontractors are required to assign one of their employees as safety coordinator. For major subcontractors, full-time health, safety, and/or medical professionals may be required, and regular formal meetings between the subcontractor and various site organizations are held.

For each subcontract, there is a qualified facility employee who is responsible for day-to-day oversight and coordination of subcontractor operations. In addition to tracking the progress of the work, this individual is responsible for checking the adequacy of the subcontractor's safety and health programs. Each facility's safety and health organization also monitors the subcontractor's compliance by conducting inspections and assessments of work areas. Improvement actions are formally communicated to the subcontractor and tracked in the same manner as other corrective actions at the facility.

HEALTH EVALUATION, DIAGNOSIS, AND TREATMENT

The occupational medicine programs at Program facilities are integrated into site operations to ensure adequate assessment of factors that affect personnel health and well being. Each facility's occupational medicine program elements are documented in the respective site's occupational medicine plan and include routine employee health examinations, as well as diagnosis and treatment of occupationally related injury and illness.

Employee Health Examinations

Routine health examinations are given to facility employees to provide initial and continuing health assessments in order to:

- Determine whether the employee's physical and mental health are compatible with the safe and reliable performance of assigned job tasks, including compliance with the Americans with Disabilities Act of 1990 (reference 12).
- Detect evidence of illness/injury and determine if there appears to be an occupational relationship.
- Contribute to employee health maintenance by providing the opportunity for early detection, treatment, and prevention of occupationally related illnesses or injuries.

Comprehensive health examinations are conducted by a licensed physician or by an Occupational Health Examiner under the direction of a licensed physician, in accordance with current accepted medical practices.

Routine health examinations/evaluations occur throughout an employee's career under the following circumstances:

- Preplacement Evaluations – Medical evaluations of job applicants are conducted before initial performance of job duties and, in the case of current employees, before a job transfer. The health status and fitness for duty of individuals is determined to ensure that assigned duties can be performed in a safe and reliable manner. Evaluations include review of applicable hazard analyses pertaining to the applicant/employee.
- Medical Surveillance Examinations and Health Monitoring – Special health examinations and health monitoring are conducted for employees who work in jobs involving specific physical, chemical, or biological hazards.
- Qualification Examinations – Examinations are conducted to qualify employees for job assignments for which specific medical qualification standards exist (e.g., special vehicle drivers, protective force personnel, and respirator wearers).

- Voluntary Periodic Examinations – Voluntary periodic examinations are offered to employees. A fundamental purpose of these examinations is to periodically assess employees' health. The frequency and type of examination offered is determined by the individual's age and work exposures.

- Return to Work From Occupational Injury or Illness – All employees with occupationally related injuries or illnesses are evaluated before returning to work. The scope of this evaluation is determined by the Occupational Health Examiner, based upon the nature and extent of the injury or illness, and is designed to ensure that the employee may return to work without undue health risk to self or others.

- Return to Work From Non-occupational Injury or Illness – Employees with significant non-occupationally related injuries or illnesses are evaluated before returning to work. The scope of the evaluation is dependent upon the nature of the injury or illness, and is undertaken to ensure that the employee may return to work without undue risk to self or others.

- Termination Health Evaluations – An examination is conducted, whenever possible, on employees with known occupational illnesses or injuries, documented or presumed exposures requiring evaluation by OSHA regulations (reference 9), or when more than a year has elapsed since the last examination. A health status review is available for all terminating employees.

Diagnosis and Treatment of Injury or Illness

All occupational injuries or illnesses, no matter how slight, are evaluated by medical personnel. Diagnosis and treatment of occupational injury or illness is prompt, with emphasis placed on rehabilitation and return to work at the earliest time compatible with employee health and job safety.

A close liaison exists between the medical and safety/health communities to ensure that the causes of occupational injuries or illnesses are fully evaluated and promptly acted upon.

Medical Services for Navy Personnel

Medical evaluation and care for Navy personnel is the responsibility of the local Naval Branch Medical Clinic. Immediate and emergency medical treatment for injuries or illnesses at DOE sites is provided by the facility medical staff, with immediate follow-up consultation with Navy medical personnel. If further diagnosis or treatment is warranted, the patient will be transported to a nearby military or civilian medical facility. Follow-up medical treatment or evaluation is provided by naval medical services.

Communication between DOE prototype facility personnel and naval medical staff is coordinated through the commanding officer of the Nuclear Power Training Unit located at that facility. Navy medical staff visit the Program DOE facilities periodically and

communicate directly with facility medical staff as appropriate to assist in proper diagnosis and treatment of naval personnel.

At the Moored Training Ship facility, personnel are served by an on-site Navy sick-call clinic and the Naval Branch Medical Clinic located elsewhere on the Charleston Naval Weapons Station site.

ACCOUNTABILITY

Independent Overview and Investigation

Naval Reactors field offices conduct frequent inspections and audits of OSHOM Programs to ascertain compliance with applicable requirements, to determine strengths and weaknesses, and to identify areas where improvement of the OSHOM programs is needed. These audits are complemented and augmented by a biennial program review by Naval Reactors Headquarters personnel and representatives from other Naval Reactors field offices.

If significant safety or health events concerning civilian or Navy personnel at Program facilities occur, a formal independent investigation board is convened that includes senior personnel knowledgeable in the topical area and Naval Reactors field office or Headquarters personnel (references 5, 6, and 13). These typically involve several person-weeks of fact finding and evaluation effort.

General Accounting Office Evaluation

In the late 1980's allegations were made concerning environmental, health, and safety practices at some Program facilities. Allegations involved employee overexposure to radiation, unsafe reactor design, problems with asbestos work practices, and improper radioactive and hazardous waste disposal. In response to these allegations, the Chairman of the House Environment, Energy, and Natural Resources Subcommittee, House Committee on Government Operations in 1989 requested a comprehensive General Accounting Office review of the Program's environmental, safety, and health practices. The review of Program facilities focused on:

- Worker health and safety.
- Radiological controls.
- Reporting.
- Environmental compliance.
- Reactor Safety.
- Adequacy of oversight.
- Classification of information to prevent disclosure of problems.

The GAO had unrestricted access to documents, facilities, and personnel within the Program, and talked in confidence with anyone who wished to discuss concerns during their 14-month investigation. In 1991, following the review, the GAO testified in a joint hearing before the Department of Defense Nuclear Facilities Panel and the Seapower Subcommittee of the House Armed Services Committee.

In their testimony and report (references 14 and 15), the GAO stated the following:

> In the past we have testified many times before this Committee regarding problems in the Department of Energy. It is a pleasure to be here today to discuss a positive program in DOE.
>
> [W]e have reviewed the environmental, health, and safety practices at Naval Reactors laboratories and sites and have found no significant deficiencies.
>
> [W]e were given full and complete access to all classified and other information needed during our work. We reviewed thousands of classified documents and could find no trend or indication that information was classified to prevent public embarrassment.
>
> GAO's review of specific environmental and safety programs at Naval Reactors facilities show no basis for allegations that unsafe conditions exist there or that the environment is being adversely affected by activities conducted there.

Given the breadth and depth of the GAO review, their conclusion represents a strong independent endorsement of the excellence and effectiveness of OSHOM programs at Program facilities.

Internal Overview and Self Appraisals

OSHOM organizations at each Program facility perform frequent and detailed inspections to determine the effectiveness with which OSHOM programs are implemented by operating personnel at the facility. Similarly, the OSHOM organizations perform self-appraisals of their own activities and programs to identify areas where improvements are appropriate. The minimum acceptable standard of performance is full compliance with applicable rules, regulations, and standards as defined in the HSSRD.

MEASURES OF PERFORMANCE

The Naval Reactors Program facilities track numerous performance indicators to measure OSHOM effectiveness. The indicators used are consistent with those employed by general industry and the DOE. These indicators are developed using criteria established by the Bureau of Labor Statistics (BLS) in their Recordkeeping Guidelines (reference 16). The data provided for general industry, based on BLS criteria, were obtained from the Bureau of Labor Statistics (reference 17). BLS data for 2002 are not currently available. Effective January 1, 2002, OSHA established new occupational injury and illness reporting criteria (reference 16). Based on this change, Figures 2 and 3 have been changed to restricted workday case rate and days away from work case rate (in lieu of lost workdays and lost workday case rate). While different from previous year's reports, these statistics provide a standard measure of the Program's trends relative to the DOE and general industry. The DOE data in Figures 1 through 3 in this report are taken from injury and illness data as presented by the DOE (reference 18).

Fatalities

The Program has experienced no occupationally related fatalities of civilian or military personnel resulting from current operations at its facilities for the 5-year period covered by this report and has experienced three fatalities (all of which were subcontractor personnel) since the passage of the OSH Act in 1970. Two of the fatalities were due to falls and the third fatality was an individual who committed suicide while on site.

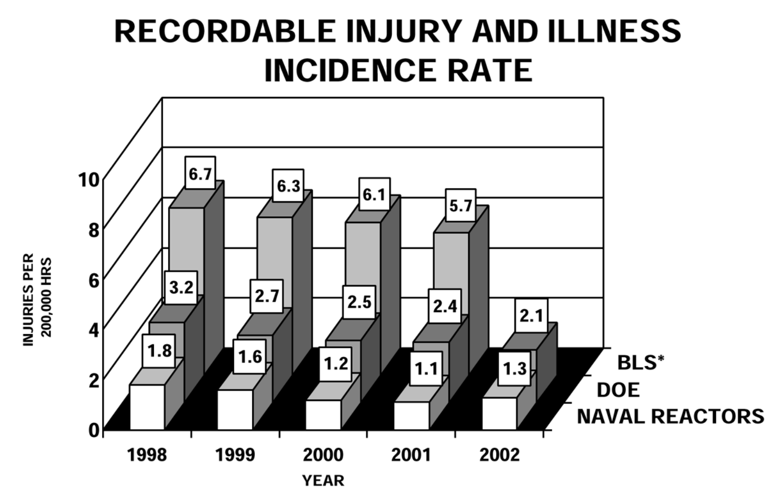

FIGURE 1

Recordable Injury and Illness Incidence Rate

The total recordable injury and illness incidence rates for the civilian work force in the Naval Reactors Program[1], DOE, and general industry (BLS) are shown in Figure 1. As shown by Figure 1, the Program's injury and illness rates have remained lower than the comparable DOE rates and substantially lower than the BLS total industry rates.

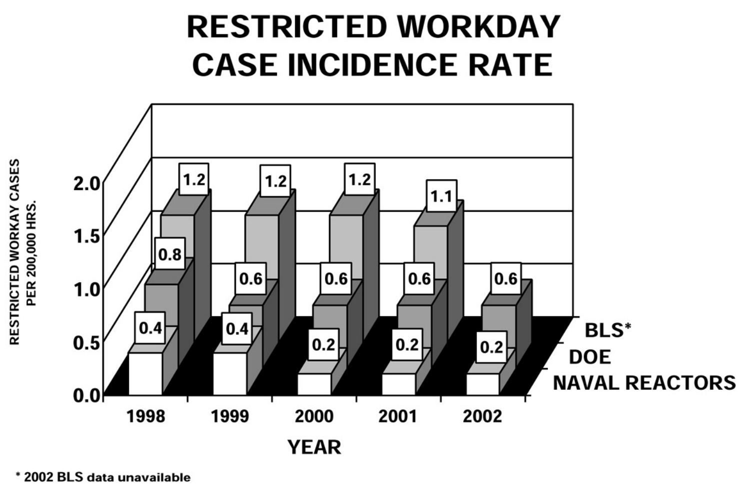

FIGURE 2

Restricted Workday Case Incidence Rate and Days Away From Work Case Incidence Rate

The BLS recording criteria require that all cases involving injuries or illnesses in the course of work needing treatment beyond first aid be recorded. However, this does not indicate the severity of an injury or illness; it merely shows that an injury or illness has occurred. For example, a cut requiring sutures, a broken arm, or a disabling back injury is not distinguishable in the reporting system; each of these would be counted as one injury in the reported data. The severity of recordable cases is indicated by two other means: by the number of cases that result in individuals having their work activity restricted and by the number of cases that require one or more days away from work.

[1]Naval Reactors Program civilian workforce data in Figures 1 through 4 consist of data for civilian prime contractor and subcontractor personnel.

Injuries and illnesses reported in the Program are generally minor, such as cuts and abrasions, and require little or no time lost from work. Figure 2 shows the Naval Reactors Program, DOE, and general industry (BLS) rates of occupational injury or illness cases, which resulted in individuals having their work activity restricted one or more workdays. Figure 2 includes cases that have only restricted days. If the cases have days away from work and restricted days, the cases are in Figure 3. Figure 2 shows that the Program's restricted workday case incidence rates are lower than the DOE rates and substantially lower than the BLS general industry rates.

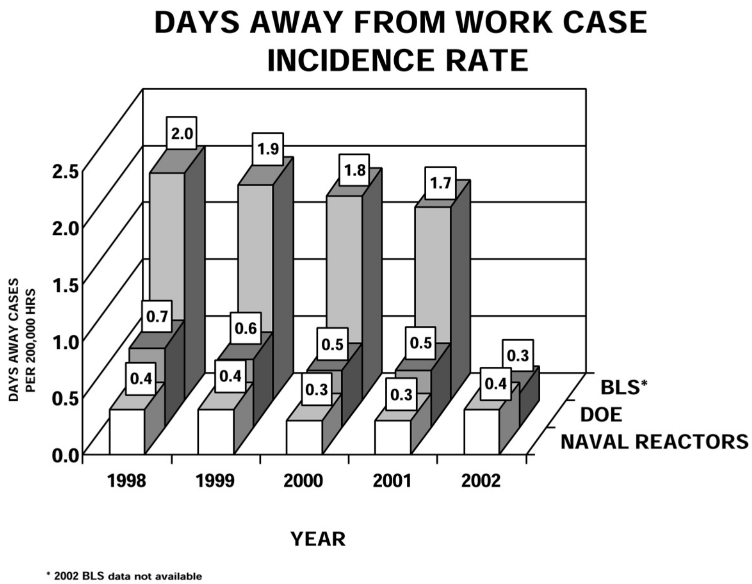

FIGURE 3

Figure 3 shows the days away from work case incidence rate, the number of cases, which result in one or more days away from work due to occupational injuries and illnesses. This figure shows that the rate of days away from work cases at Naval Reactors Program facilities is significantly below that of general industry. The general industry rates are obtained from data published by the BLS.

Because significant differences exist between Navy injury and illness reporting criteria and the BLS criteria (i.e., the Navy has a higher threshold than that used by the BLS), combining civilian and military injury and illness data is not meaningful, nor is it a direct comparison of Navy performance indicators (reference 19) to DOE or BLS indicators.

Therefore, the data for the Naval Reactors Program shown in Figures 1 through 3 do not include Navy personnel.

However, the Program tracks active-duty Navy personnel injury and illness recordable case rates and lost workday case incident rates using the BLS criteria. For 2002, the injury and illness recordable incidence rate for Navy personnel at Program facilities, using the BLS criteria, was 0.9 per 200,000 hours worked. The restricted workday case incidence rate was 0.1 cases that required one or more restricted workdays per 200,000 hours worked. The days away case incidence rate was 0.1 that required one or more days away from work per 200,000 hours worked.

If the higher Navy threshold for reporting injuries and illnesses is applied to Naval Reactors Program data (civilian and military personnel), the Program's performance is better than the overall Navy's.

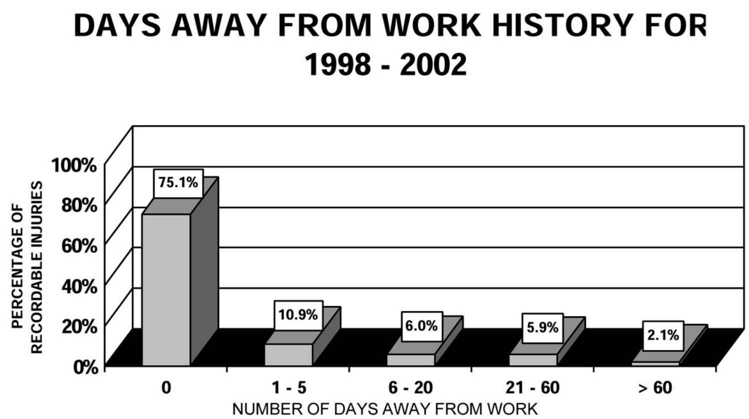

FIGURE 4

<u>History of Cases Involving Days Away From Work</u>

A further indication of Program injury and illness severity comes from a review of the history of cases resulting in days away from work (excluding cases with only restricted workdays). Figure 4 shows the Program's history of cases involving days away from work that were reported from 1998 to 2002 and the corresponding number of days away. As shown in Figure 4, 86 percent of the recordable injuries and illnesses resulted in either no days away from work or resulted in a relatively short period of time away from work (fewer than 6 days).

Accident Investigations

Occupational illnesses or accidents involving injury of civilian or military personnel at Program DOE facilities are formally investigated by the Program. These events are categorized and investigated depending on the nature and severity of the occurrence. The DOE categorizes the most serious events as Type A (e.g., a fatality) and Type B (e.g., serious injury requiring hospitalization). A third category, Type C, is for less serious events subject to routine investigation by contractor personnel (reference 13). A similar classification system exists in the Navy's NAVOSH program (references 5 and 6).

The Program had no Type A or Type B safety events, as defined by reference 13, during the five years covered by this report. This compares to 19 Type A and Type B investigations for such events at DOE-wide operations (excluding Naval Reactors facilities) during the same period as reported by the DOE (references 20, 21, 22, 23, and 24). On September 11, 2002, a building subcontractor construction accident occurred at the Knolls Atomic Power Laboratory. Four improperly braced concrete wall panels from a building under construction fell during high winds. There were no injuries. Damage was limited to the panels that fell and to the wall of an adjacent warehouse that was struck by two of the panels. Although the damage associated with this accident did not meet the DOE criteria for an official Type A or Type B investigation (reference 13), the Program nevertheless concluded that a formal accident investigation was warranted. As a result of this event and the lessons learned, corrections have been implemented at all Program sites to improve worker safety.

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(6) OPNAV Instruction 5100.19, "Navy Occupational Safety and Health (NAVOSH) Program Manual for Forces Afloat."

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(13) U.S. Department of Energy Order 225.1A, "Accident Investigations."

(14) GAO/T-RCED-91-24, "Environmental, Health and Safety Practices at Naval Reactors Facilities," GAO Testimony.

(15) GAO/RCED-91-157, "Environmental, Health and Safety Practices at Naval Reactors Facilities," GAO Report.

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